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GEOLOGICAL MAGAZINE

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On the Ages of Certain Upper Tertiary Beds of Peninsular India and Ceylon

By F. E. EAMES

ABSTRACT

During the course of researches upon the Cainozoic faunas of Burma, Pakistan, India, and Ceylon, the writer has compiled a list of all the species that have been recorded, and has assessed the accuracy of the information from the points of view of both specific identification and age. As a consequence, he has been led to believe that current opinions as to the ages of certain horizons may have to be modified, and that in other cases the evidence of age is much less certain than was believed. The faunas here discussed are those of the Miocene beds of Ceylon, of the Quilon limestone, of the Pliocene of Karikal, and of the Cuddalore sandstones.

I. THE CEYLON MIOCENE

THE Miocene beds of Ceylon were described by Wayland, and the palaeontological evidence considered by Dr. A. M. Davies (1923). Dr. Davies's work necessitated a comparison of the Ceylon fossils with the material from Western Pakistan and India, that had been described by d'Archiac and Haime (1854). He was, however, handicapped in his work by the fact that the revision of d'Archiac and Haime's fossils—a task to which Vredenburg, Dr. L. R. Cox, Colonel L. M. Davies, and Dr. W. L. F. Nuttall have, among others, contributed—was not available. A few forms which he identified as, or compared with, species now known to be of Eocene age are actually more closely comparable with or identifiable as species of Miocene age. A revised faunal list for the Ceylon Miocene beds, together with the distribution of the species elsewhere, is given in Appendix I.

Dr. A. M. Davies (1923, p. 590) regarded the northern Ceylon beds as of uppermost Vindobonian or Pontian age, and the southern Ceylon beds as Upper Vindobonian, although later (p. 591) he was more in favour of a "Lower to Upper" Vindobonian age for the latter. His conclusions seem to have been based primarily on the occurrence of *Ostrea* (*Lopha*) *virleti* Deshayes and *Archaias malabaricus*

(Carter).[1] Furon and Lemoine (1939) regarded the Ceylon beds as being of Tortonian age, and Furon later (1943) regarded them as Helvetian-Tortonian. So far as the writer knows there is no published work suggesting an age older than Middle Miocene for these Ceylon beds.

The name *Ostrea* (*Lopha*) *virleti* is used here for those forms from the Indo-Pacific region and the Middle East which are usually referred to the species by palaeontologists. In a fairly recent publication, however, Ranson (1945) pointed out that the *Ostrea hyotis-virleti* group as defined by palaeontologists is the Mediterranean *Ostrea plicatula* of palaeontologists (not the tyipcal *O. plicatula* from America), the correct name for which should be *Ostrea squarrosa* de Serres. While placing the type of *Ostrea virleti* in the genus *Gryphea*, he regarded *O. squarrosa* as belonging to the genus *Pycnodonta*. Since his distinction of ostreid genera by means of the characters of the prodissoconch results in divorcing apparently closely related forms, and in placing forms with quite a different appearance close together in the classification, it is necessary to apply the results of his work with circumspection. In any case, it is evident that a study of a series of specimens from the type localities of each of the species concerned is necessary before a reliable conception of the species *O. virleti* can be obtained, and that the species, as now interpreted by palaeontologists to range from Lower Miocene to Pliocene, cannot be used for precise dating of beds within the Miocene and Pliocene.

The writer has recently re-examined those specimens from the Miocene of Ceylon which had been referred to species that had been recorded previously only from pre-Miocene horizons ; the reference, either definite or tentative, to pre-Miocene species seems unlikely, and the following table gives the results of the writer's revision of these forms :—

Previous Determination.	*Present Determination.*
Spondylus rouaulti d'A. & H. (Eocene, Spain to India).	*Spondylus* aff. ? *tallavignesi* d'A. & H.
Cardium sharpei (?) d'A. & H. (Ranikot of Sind).	? *Discors triforme* (J. de C. Sowerby).
Xenophora cumulans (Brongniart) (Eocene of Italy).	" *Xenophora* " sp.
Trapezium [*Cypricardia*] *carteri* (d'A. & H.) (Laki and Khirthar of Western Pakistan).	? *Macrocallista* (*Costacallista*) *pseudo-umbonella* (Vredenburg).
Corbis subelliptica ? d'A. & H. (Laki and Khirthar of Western Pakistan ; Eocene of Europe, Africa, and W. Asia).	*Antigona puerpera* (Linné) var. *granosa* J. de C. Sowerby.

[1] Since this paper was in proof, *Archaias malabaricus* (Carter) has been referred to the genus *Taberina* (F. R. S. Henson, *Middle Eastern Tertiary* Peneroplidae (*Foraminifera*) . . ., Wakefield, 1950, p 50).

All the species and varieties mentioned in the second column are known from the Gaj series. Of the whole fauna, *Archaias malabaricus* is the only species which is restricted to beds of known Middle Miocene age beyond the India–Pakistan–Ceylon area. *Callistocypraea* (*Miolyncina*) *prunum* (J. de C. Sowerby), *Conus* (*Lithoconus*) *subbrevis* d'A. & H., *Euspirocrommium oweni* (d'A. & H.), *Ptychocerithium archiaci* (Vredenburg), *Tectus loryi* (d'A. & H.), *Anadara peethensis* (d'A. & H.), *Cypraea* (*Lynciya*) *jenkinsi* d'A. & H., *Trachycardium picteti* (d'A. & H.), *Venericardia sowerbyi* (d'Orbigny), *Spiroclypeus orbitoideus* Douvillé, *Clypeaster* (*Paleanthus*) *depressus* J. de C. Sowerby, *Montlivaltia brevis* Duncan, and *Staminocoenia plana* (Duncan) do not, as far as the writer is aware, occur higher elsewhere than in beds believed on good grounds to be of Lower Miocene age (e.g. the Gaj of Sind and Cutch, and the Miocene " e " of the Netherlands East Indies).

These Ceylon faunas are, in fact, of characteristic Gaj (Lower Miocene) type and, on comparison with the faunas from Sind and Cutch, would appear to be of Upper Gaj age. Of other marine horizons, it seems probable that the lowest fossiliferous beds of the Mekran series (i.e. just below the Talar stage) are not older than Sarmatian in age. These factors, together with other suggestions which are now put forward, mean that there may be no good marine faunas of Middle Miocene age in India or Pakistan with which the Ceylon faunas could be compared. Nevertheless, the latter are representative of the type of fauna found in the Gaj.

II. The Quilon Limestone

The more important papers dealing with the Quilon faunas are those by Carter (1853, 1857, 1861), Foote (1876), King (1882), Douvillé (1902), Dr. A. M. Davies (1923, 1935), Kumar & Pichamuthu (1933), and Furon & Lemoine (1939).

Quilon is the type locality for *Archaias malabaricus* (Carter),[1] and the occurrence was regarded as of Pliocene age by Carter (1853, p. 426) and Douvillé (1902, p. 300). Carter's reference to an Eocene age (1857, pp. 630, 634) was due to the mistaken impression that all d'Archiac & Haime's fossils came from the Eocene. In 1923 Dr. A. M. Davies (1923, p. 590) regarded the Quilon fauna as Vindobonian, but in 1935 he referred the Travancore and Ceylon occurrences of *Archaias malabaricus* to the Middle Miocene on p. 17, and the Ceylon occurrence to the Lower Miocene on p. 19 (Fig. 26*f*), although the latter reference appears to be an oversight or printer's error. In 1923 (1923, p. 590) he correlated the Quilon beds with the southern

[1] See footnote on opposite page.

Ceylon beds, and regarded both as being of Vindobonian age. Kumar & Pichamuthu (1933) have subsequently correlated the Quilon fauna with that of the Gaj, pointing out that it contained a mixture of Burma and Sind types. Furon & Lemoine (1939) considered the Quilon fauna to be of Tortonian age.

The Quilon fauna has been regarded as of Vindobonian age, not on account of any similarity with known Vindobonian faunas elsewhere, but arbitrarily on account of the presence of *Archaias malabaricus* in quantity at Quilon and in Ceylon. The presence, however, of *Dientomochilus subrimosus* (d'Orbigny), *Nucula warsarensis* Eames, *Conus* (*Leptoconus*) *marginatus* J. de C. Sowerby, and *Ptychocerithium rude* (J. de C. Sowerby) in the Quilon fauna does tend to support Kumar & Pichamuthu's correlation of the fauna with that of the Gaj. A further fact of some possible significance is that Carter (1857, pp. 630, 634 ; 1861, p. 462) recorded a " small variety " of *Archaias malabaricus* from Porbander (41 G/10, B. 2) on the Kathiawar coast, from beds now believed to be an extension of the Gaj outcrops of Cutch. The most significant evidence, however, is that *Archaias malabaricus* was found fairly commonly in collections made, by geologists of the Burmah Oil Co., Ltd., from the Gaj series of the Gaj River section, which is the type area for the Gaj series. Taking the evidence as a whole, these Ceylon, Quilon, and Kathiawar faunas all seem to be of the same age (probably Upper Gaj—i.e. upper part of Lower Miocene), and the beds in which they were found were probably all formed during the same Lower Miocene transgression as were the marine Gaj deposits of Sind and Cutch.

Mr. F. R. S. Henson (1949) has recently recorded *Archaias malabaricus* from the Middle Miocene of the Persian Gulf area and north-west Syria. The writer has discussed with him the distribution of the species, and there seems to be no doubt of the Middle Miocene age of these occurrences. The Middle Miocene age of the Lower Fars series, in which the species was found, is based on (*a*) its occurrence as a widely transgressive unit homotaxial with proven transgressive Middle Miocene of the Levant and Cyprus, (*b*) the occurrence beneath it, in residual basins only, of earlier Miocene beds whose age is indicated by fossils to be Lower Miocene, and (*c*) the occurrence in fresh-water beds a short distance conformably above the top of the Lower Fars of a Pontian vertebrate fauna. However, the change from a Lower Miocene type of fauna to a Middle Miocene type of fauna may not have taken place at exactly the same time in Western Pakistan and India and in the Middle East, since it was probably dependent, to a certain extent, upon earth movements which were not exactly contemporaneous in the two regions. There may, therefore, be little difference in age, if any, between the Iraq and Persia occurrences

assigned to the Vindobonian, and the Pakistan, India, and Ceylon occurrences believed by the writer to belong probably to the upper part of the Lower Miocene. The Iraq and Persia records do not, in other words, preclude the correlation of the Ceylon and Quilon beds with the Gaj of Sind and Cutch, or preclude their being of Burdigalian age. It is, of course, also possible that the palaeontological record is as yet incomplete, and that the species may eventually be found in the Middle East in beds of Lower Miocene age also.

III. The Karikal Pliocene

The Karikal fauna was recorded in a series of papers by Cossmann (1900, 1903, 1910, 1923), and all published references to it have unhesitatingly referred to it as Pliocene.

The fauna is a large one, consisting of 193 mollusca, and is listed in Appendix III. Of these forms, twenty-four have such long ranges (e.g. Oligocene to Recent) that they have no bearing on the precise age. There are also ten forms concerning which more information with regard to specific identification or distribution is required; some of these may be forms which range up to but not above the Karikal horizon, and which would consequently give to any consideration of the fauna a false bias in favour of a somewhat older age. One hundred and three forms have not been recorded from any other locality or horizon, although six of these have been found elsewhere in collections made by the geologists of the Burmah Oil Co., Ltd. In the Karikal fauna there also appear to be twenty-five forms which were previously known only from the Recent faunas of the Indo-Pacific region. The writer has not had much opportunity for studying the marine Pliocene and Quaternary faunas of this region except for those of the India, Pakistan, Ceylon, and Burma area, and for some of the older records from the Netherlands East Indies. Although some of these twenty-five forms may actually occur in some of the late Cainozoic deposits, the writer has not encountered any record of them from the Miocene, and there is no doubt that they constitute a very modern element in the fauna. In addition to them, there are seventeen forms which were not known previously to occur below the Pliocene elsewhere (five of these are apparently restricted to the Pliocene), and nine forms which have not yet been recorded from below the Upper Miocene.

There is thus a considerable weight of evidence in favour of a Pliocene age. There are far more forms (forty-two) relating the fauna to Pliocene and later horizons than forms (ten) relating it to Miocene horizons. This evidence has been considered here as there are certain beds in the Arakan Coast region of Burma which have been called the Tipam standstones, and which have yielded a rich comparable fauna.

These sandstones overlie Boka Bil beds containing the usual Burdigalian fauna, and the field and petrological evidence has been taken to indicate a correlation with the Tipam sandstones of the Surma Valley, in which case they would be of Middle Miocene age. There is, however, a palaeontological break between the Boka Bil fauna and the fauna of the overlying sandstones. Both faunas are of closely comparable type (predominantly molluscan) and, while they are each of fairly uniform composition over some considerable thickness of strata, they are sometimes separated by only a few feet of unfossiliferous beds. Such evidence, in a succession of clastic sediments such as these, is normally taken to indicate a hiatus in the succession, and does not seem to be consistent with the implications of the petrological evidence. Geological observations between the Surma Valley and the Arakan Coast region are by no means as complete as is desirable, and considerable stretches of country remain unexamined. Any bearing these faunas may have on the age of the Karikal fauna is complicated by the incomplete and inconsistent nature of the evidence from the Arakan Coast region, and any implications are dependent on an inferred, but not proved, correlation. Consequently, the writer does not consider that the evidence at present available from the Arakan Coast throws any doubt on the Pliocene age of the Karikal fauna, although some other geologists, impressed by the large number of species of unknown affinities, and by the other evidence, are doubtful about the age of the Karikal fossils.

IV. The Cuddalore Sandstones

The Cuddalore sandstones of eastern and southern Peninsular India have been believed to overlie the Karikal beds and to be of Pontian age, although Furon (1943) has drawn attention to the fact that the contact between them has nowhere been seen, and has pointed out that their stratigraphical relationships remain uncertain.

The only fossil of common occurrence in the Cuddalore sandstones (which include the Trivicary grits as their basal member) is *Mesembryoxylon* [*Peuce*] *schmidianum* (Schleiden), a fossil wood. This species has often been recorded in literature, and has been held to indicate a Pontian age. There are, however, a few other fossils which have been recorded, with greater or less certainty, from the Cuddalore sandstones. Foote (1883) recorded the species *Anadara granosa* (Linné) from beds at Yellada Odai (= Thopevella ; 58 H/15, A. 3) which he referred doubtfully to the Cuddalore sandstones. His record of *Arca rugosa* (1883*a*) from the Cuddalore sandstones of the Nambiyar River (58 H/11, 15, 16) is evidently a *lapsus calami* for *Arca granosa*, since *A. rugosa* dates from Muenster, 1841, and is a Triassic species. *Anadara granosa* is of fairly common occurrence

in the Indo-Pacific region where it is known to range from Upper Miocene to Recent. More recently, C. R. N. Rao (1932) recorded *Crocuta crocuta* (Erxleben) and *Crocuta pilgrimina* sp. nov. from beds at Sendurai (58 M/3, C. 3) which have been referred doubtfully to the Cuddalore sandstones. *Crocuta crocuta* is a mammal of very modern type, and occurs in the Pleistocene faunas of the Karnul Caves (57 I/3, C. 1) and of Europe, and in the Recent faunas of Africa.

Furon (1943, pp. 20, 26), while recalling that the Cuddalore sandstones rest on the Pre-Cambrian at Cuddalore and on Cretaceous and Eocene beds near Pondicherry, believed them to be equivalent to the " Pontian-Pliocene " Irrawaddy system of Burma, more particularly Pliocene as far as the fossil wood was concerned. He also regarded the rich marine Karikal fauna as a local development of the upper part of the Cuddalore sandstones, a hypothesis which, in view of the widespread distribution of the normal type of Cuddalore sandstones, seems difficult to believe. If, however, the species of *Crocuta* really did come from the Cuddalore sandstones, then part, at any rate, of the Cuddalore sandstones is of considerably younger age than Pliocene. Consequently it seems possible that the Pliocene Karikal beds are actually overlain by the Cuddalore sandstones, a supposition which resolves many of the difficulties associated with previous opinions of the stratigraphical succession. In this connection it has to be remembered that *Mesembryoxylon schmidianum* has been found only in the Cuddalore sandstones, and hence cannot be used to date these beds so precisely as has been done hitherto.

V. Conclusions

A review of the palaeontological evidence from marine Neogene deposits in India, Pakistan, and Ceylon has suggested to the writer that, apart from some of the lowest horizons of the Mekran series of the Mekran Coast, there may be no marine deposits which have yielded any fauna of reasonable size and which could unquestionably be regarded as of Middle or Upper Miocene age. The geological history of the East African coast, where no marine faunas between the Lower Miocene and the Pliocene have been recognized, was apparently very similar.

It seems probable that the Miocene beds of Ceylon and Quilon are of Lower Miocene (Burdigalian) age, and correlate with horizons in the Gaj of Cutch and Sind, the faunas of all these beds being very closely comparable. Although it has been suggested to the writer that the Karikal fauna might be of Middle Miocene age, its composition is not in accord with such a view, and the fauna is best regarded, as hitherto, as being of Pliocene age on account of its modern

aspect. Furthermore, there appears to be no satisfactory palaeontological evidence for regarding the Cuddalore sandstones as being of Pontian age, and the writer suggests that they may be younger and overlie, instead of underlie, the Karikal beds ; this would resolve many of the difficulties associated with the previous conception of the stratigraphical succession in this part of India.

The views here expressed indicate that marine faunas of Middle Miocene age from Pakistan, India, or Ceylon may be difficult to determine as Middle Miocene owing to the lack of any basis for comparison in these areas. It is to be expected, however, that they would be intermediate in character between the distinctive Gaj and Karikal faunas.

APPENDIX I

Ceylon Faunas

(*Note.*—" (a) ", correct ; " (b) ", requiring checking)

A. *Kirimalai* (58 O/13, C. 3 ; approx. 9° 47′ : 79° 58′)

Original Determination.	*Present Determination and Distribution.*
Ovula ellipsoides d'A. & H. var. b d'A. & H.	(a) *Callistocypraea* (*Miolyncina*) *prunum* (J. de C. Sowerby). (Gaj of Cutch and Sind.)
Conus brevis J. de C. Sowerby .	(a) ? *Conus* (*Lithoconus*) *litteratus* Linné. (L. Miocene to Recent-Indo-Pacific, Timor to Cutch.)
Conus sub-brevis d'A. & H. . .	(b) *Conus* (*Lithoconus*) *subbrevis* d'A. & H. (Gaj of Sind.)
Phasianella oweni d'A. & H. .	(a) *Euspirocrommium oweni* (d'A. & H.) (Ranikot to L. Miocene ; Sumatra to C. Europe.)
Natica rostalina ? Jenkins . .	(b) *Natica rostalina* Jenkins. (L. Miocene to Pliocene ; Java to Karikal.)
Oliva pupa J. de C. Sowerby .	(a) *Olivancillaria* (*Anazola*) *nebulosa* (Lamarck) var. *pupa* (J. de C. Sowerby). (M. Oligocene (Padaung) to M. Miocene (Obogon) ; Burma to Sind and Cutch.)
Semicassis booleyi (G. B. Sowerby)	(b) *Phalium* (*Semicassis*) *booleyi* (G. B. Sowerby). (Recent.)
Cerithium pseudocorrugatum ? d'Orbigny.	(b) *Ptychocerithium archiaci* (Vredenburg)/*pseudocorrugatum* (d'Orbigny). (Gaj of Sind and Cutch.)
Trochus cognatus J. de C. Sowerby	(a) *Tectus loryi* (d'A. & H.). (Gaj of Cutch and Sind.)
Arca peethensis ? d'A. & H. . .	(b) *Anadara peethensis* (d'A. & H.). (Gaj of Sind.)
Pecten favrei d'A. & H. . .	(a) *Chlamys senatoria* (Gmelin). (M. Oligocene (Padaung) to Recent ; widespread in Middle and Far East.)
Spondylus rouaulti d'A. & H. .	(a) *Spondylus* aff. ? *tallavignesi* d'A. & H. (Gaj of Sind.)

Original Determination.	*Present Determination and Distribution*
Cardium sharpei ? d'A. & H. .	(a) ? *Discors triforme* (J. de C. Sowerby). (Gaj of Cutch and Sind.)
Orbiculina malabarica (Carter) .	(a) *Archaias malabaricus* (Carter). (Quilon limestone ; Miocene of Kathiawar ; M. Miocene of Persian Gulf and N.W. Iraq.)

B. *N. of Pamparippu* (58 P/15, B. 2 ; approx. 8° 20¼′ : 79° 53′)

Pecten favrei d'A. & H. . .	(a) *Chlamys senatoria* (Gmelin). (M. Oligocene (Padaung) to Recent ; widespread in Middle and Far East.)
Orbiculina malabarica (Carter) .	(a) *Archaias malabaricus* (Carter). (Quilon limestone ; Miocene of Kathiawar ; M. Miocene of Persian Gulf and N.W. Syria.)

C. *Puttalam* (58 P/16, A. 1–B. 1 ; 8° 2¼′ : 79° 50′)

Orbiculina malabarica (Carter) .	(a) *Archaias malabaricus* (Carter). (Quilon limestone ; Miocene of Kathiawar ; M. Miocene of Persian Gulf and N.W. Syria.)

D. *East of Kankesanturai* (67 C/1, A. 3 ; approx. 9° 48½′ : 80° 2½′)

Conus brevis J. de C. Sowerby .	(a) *Conus* (*Lithoconus*) *litteratus* Linné. (L. Miocene to Recent ; Indo-Pacific—Timor to Cutch.)

E. *Near Pallai* (67 C/6, A. 2–B. 2 ; approx. 9° 36¼′ : 80° 20′)

Orbiculina malabarica (Carter) .	(a) *Archaias malabaricus* (Carter). (Quilon limestone ; Miocene of Kathiawar ; M. Miocene of Persian Gulf and N.W. Syria.)

F. *Minihagalkanda* (68 F/11, A. 1 ; approx. 6° 26′ : 81° 30¾′)

Ovula ellipsoides ? d'A. & H. .	(a) *Callistocypraea* (*Miolyncina*) *prunum* (J. de C. Sowerby). (Gaj of Sind and Cutch.)
Conus brevis J. de C. Sowerby .	(a) *Conus* (*Lithoconus*) *litteratus* Linné. (L. Miocene to Recent ; Indo-Pacific—Timor to Cutch.)
Cypraea prunum ? J. de C. Sowerby	(a) *Cypraea* (*Lyncina*) *jenkinsi* d'A. & H. (Gaj of Sind.)
Phasianella oweni d'A. & H. .	(a) *Euspirocrommium oweni* (d'A. & H.) (Ranikot to L. Miocene ; Sumatra to C. Europe.)
Cerithium pseudocorrugatum ? d'Orbigny.	(b) *Ptychocerithium archiaci* (Vredenburg)/*pseudocorrugatum* (d'Orbigny). (Gaj of Sind and Cutch.)
Trochus cognatus J. de C. Sowerby	(a) *Tectus loryi* (d'A. & H.) (Gaj of Sind and Cutch.)
Trochus subcognatus d'A. & H. .	(b) *Tectus loryi* (d'A. & H.). (Gaj of Sind and Cutch.)
Xenophora cumulans (Brongniart) .	(a) " *Xenophora* " sp.
Amusium subcorneum (d'A. & H.) .	(a) *Amusium subcorneum* (d'A. & H.) (U. Nari to Gaj (common), Manchhar/Gaj Passage beds ; Sind and Cutch.)

Original Determination.	*Present Determination and Distribution.*
Chione (?) *cancellata* (J. de C. Sowerby).	(a) *Antigona puerpera* (Linné) var. *granosa* J. (de C. Sowerby). (Common in Miocene, especially L. and M. Miocene; Java to C. Europe.)
Chione (*Omphaloclathrum*) *granosa* (J. de C. Sowerby).	(a) *Antigona puerpera* (Linné) var. *granosa* (J. de C. Sowerby). (Common in Miocene, especially L. and M. Miocene; Java to C. Europe.)
Ostrea virleti Deshayes . .	(a) *Ostrea* (*Lopha*) *virleti* Deshayes. (Common in Miocene, including Kyaukkok of Burma and Burdigalian of Persia; Burma to Mediterranean.)
Pinna pachyostraca A. M. Davies .	(a) *Pinna pachyostraca* A. M. Davies.
Trapezium [*Cypricardia*] *carteri* ? (d'A. & H.).	(a) ? *Macrocallista* (*Costacallista*) *pseudo-umbonella* (Vredenburg). (Gaj of Cutch.)
Spondylus waylandi A. M. Davies .	(a) *Spondylus waylandi* A. M. Davies.
Trachycardium (?) *picteti* (d'A. & H.).	(a) *Trachycardium picteti* (d'A. & H.). (Gaj of Sind and Kathiawar.)
Cardita sowerbyi d'Orbigny . .	(a) *Venericardia sowerbyi* (d'Orbigny). (Gaj of Cutch.)
Corbis subelliptica ? d'A. & H. .	(a) *Antigona puerpera* (Linné) var. *granosa* (J. de C. Sowerby). (Common in Miocene, especially L. and M. Miocene; Java to C. Europe.)
Spiroclypeus orbitoideus H. Douvillé.	(a) *Spiroclypeus orbitoideus* H. Douvillé. (Miocene "e" (i.e., L. Miocene) of Netherlands East Indies.)
Clypeaster depressus J. de C. Sowerby.	(a) *Clypeaster* (*Paleanthus*) *depressus* J. de C. Sowerby. (Gaj of Sind and Cutch.)
Montlivaltia brevis Duncan . .	(a) *Montlivaltia brevis* Duncan. (? Gaj of Sind.)
Hydnophora plana ? Duncan .	(b) *Staminocoenia plana* (Duncan). (Gaj of Sind.)

APPENDIX II

Quilon Faunas

A. *Chattanur* (58 D/9, C. 2; 8° 51¾′ : 76° 43′)

Original Determination.	*Present Determination and Distribution.*
Conus hanza Noetling . .	(b) *Conus* (*Leptoconus*) *hanza* Noetling. (Miocene of Burma, including Obogon.)
Rimella subrimosa (d'Orbigny) .	(a) *Dientomochilus subrimosus* (d'Orbigny). (Gaj of Cutch.)
Arca theobaldi Noetling . .	(b) *Anadara theobaldi* (Noetling). (Miocene of Burma, including Kyaukkok.)

Original Determination.	*Present Determination and Distribution.*
Nucula cancellata Vredenburg, 1928 *non* Meek & Hayden, 1856 *nec* Jeffreys 1881.	(a) *Nucula warsarensis* Eames. (Gaj of Cutch.)
Parallelepipedum prototortuosum Noetling.	(b) *Trisidos prototortuosum* (Noetling). (Miocene of Burma, including Kyaukkok.)
Orbiculina malabarica (Carter) .	(a) *Archaias malabaricus* (Carter). (Miocene of Ceylon and Kathiawar ; M. Miocene of Persian Gulf and N.W. Syria.)
Stylophora pulcherrima d'Achiardi	(b) *Stylophora pulcherrima* d'Achiardi. (L. Nari of Sind ; Oligocene of Italy.)
B. *Nedungolam* (58 D/9, C. 2 ; 8° 50½′ : 76° 41½′)	
Rimella subrimosa (d'Orbigny) .	(a) *Dientomochilus subrimosus* (d'Orbigny). (Gaj of Cutch.)
Arca theobaldi Noetling . .	(b) *Anadara theobaldi* (Noetling). (Miocene of Burma, including Kyaukkok.)
Nucula cancellata Vredenburg, 1928 *non* Meek & Hayden, 1856 *nec* Jeffreys, 1881.	(a) *Nucula warsarensis* Eames. (Gaj of Cutch.)
Parallelepipedum protortuosum Noetling.	(b) *Trisidos prototortuosum* (Noetling). (Miocene of Burma, including Kyaukkok.)
Orbiculina malabarica (Carter) .	(a) *Archaias malabaricus* (Carter). (Miocene of Ceylon and Kathiawar ; M. Miocene of Persian Gulf and N.W. Syria.)
C. *Padappakara* (58 D/9, B. 1 ; 8° 58½′ : 76° 38′)	
Conus catenulatus J. de C. Sowerby	(a) *Conus* (*Lithoconus*) *litteratus* Linné. (L. Miocene to Recent ; Indo-Pacific, Timor to Cutch.)
Voluta jugosa J. de C. Sowerby .	(a) *Lyria jugosa* (J. de C. Sowerby). (L. Miocene to U. Miocene ; Netherlands East Indies, Cutch, and Sind.)
Strombus fortisi Brongniart . .	(a) *Strombus* (*Labiostrombus*) *sedanensis* Martin. (Gaj of Kathiawar and Sind ; L. Miocene of Java ; U. Miocene of Borneo.)
Nucula cancellata Vredenburg, 1928 *non* Meek & Hayden, 1856 *nec* Jeffreys, 1881.	(a) *Nucula warsarensis* Eames. (Gaj of Cutch.)
Parallelepipedum prototortuosum Noetling.	(b) *Trisidos prototortuosum* (Noetling). (Miocene of Burma, including Kyaukkok.)
Orbiculina malabarica (Carter) *Orbitolites malabarica* Carter	(a) *Archaias malabaricus* (Carter). (Miocene of Ceylon and Kathiawar ; M. Miocene of Persian Gulf and N.W. Syria.)
D. *Quilon Area* (58 D/9, B. 2)	
Ranella bufo J. de C. Sowerby .	(a) *Argobuccinum* (*Biplex*) *perca* (Perry). (L. Miocene to Recent ; Indo-Pacific.)

Original Determination.	*Present Determination and Distribution.*
Conus marginatus J. de C. Sowerby	(a) *Conus* (*Leptoconus*) *marginatus* J. de C. Sowerby. (Gaj of Cutch.)
Cassis sculpta J. de C. Sowerby .	(a) *Phalium* (*Semicassis*) *sculptum* (J. de C. Sowerby). (Gaj of Cutch ; Pliocene of Karikal.)
Cerithium rude J. de C. Sowerby .	(a) *Ptychocerithium rude* (J. de C. Sowerby). (Gaj of Sind, Cutch, and Kathiawar.)

APPENDIX III

Karikal Fauna

(58 N/13, A. 1–2, B. 1–2 ; 10° 55′ : 79° 50′)

Original Determination.	*Present Determination and Distribution.*
Streptosiphon couderti (Petit) .	(a) " *Afer* " *couderti* (Petit). (Recent.)
Streptosiphon macrospira Cossmann.	(a) *Afer macrospira* Cossmann.
Ancilla (*Sparellina*) *candida* Lamarck.	(a) *Ancilla* (*Sparellina*) *candida* Lamarck. (Recent.)
Ancilla (*Sparella*) *cinnamomea* (Lamarck)	(a) *Ancilla* (*Sparella*) *cinnamomea* (Lamarck). (L. Miocene to Recent ; Java, Sumatra, Borneo.)
Ancilla (*Alocospira*) *tornata* Cossmann.	(a) *Ancilla* (*Alocospira*) *tornata* Cossmann.
Solarium maximum Philippi . .	(a) *Architectonica affinis* (J. de C. Sowerby). (M. Oligocene (Padaung) to Recent ; common in Indo-Pacific.)
Solarium karikalense Cossmann .	(a) *Architectonica karikalensis* (Cossmann).
Ranella (*Argobuccinum*) *karikalensis* Cossmann.	(a) *Argobuccinum* (*Ranella*) *bitubercularis* (Lamarck). (L. Miocene to Recent ; common in Indo-Pacific.)
Ranella margaritula Deshayes .	(a) *Argobuccinum* (*Gyrineum*) *margaritulum* (Deshayes). (Recent.)
Asthenotoma terebralis Cossmann.	(a) " *Asthenotoma* " *terebralis* Cossmann.
Anachis crassicostata Cossmann .	(a) *Atilia crassicostata* (Cossmann).
Siphonalia (*Penion*) *heptozodes* Cossmann.	(a) " *Austrosipho* " *heptozodes* (Cossmann).
Latrunculus (*Peridipsaccus*) *occlusus* Cossmann.	(a) *Babylonia* (*Peridipsaccus*) *occlusa* (Cossmann).
Latrunculus canaliculatus (Schumacher).	(a) *Babylonia spirata* (Linné). (U. Miocene to Recent ; Indo-Pacific.)
Drillia sacra Reeve . . .	(a) *Brachytoma sacra* (Reeve). (Recent.)
Calliostoma discrytum Cossmann .	(a) " *Calliostoma* " *discrytum* Cossmann.
Calliostoma inaequiliratum Cossmann.	(a) *Calliostoma inaequiliratum* Cossmann.
Melongena (*Pugilina*) *octocostata* Cossmann.	(a) *Cantharus tranquebaricus* (Martini). (Recent.)
Capulus bonneti Cossmann . .	(a) *Capulus bonneti* Cossmann.
Cerithidea gibbosula Cossmann .	(a) *Cerithidea gibbosula* Cossmann.
Cerithidea trifunata Cossmann .	(a) *Cerithidea trifunata* Cossmann.

Original Determination.	*Present Determination and Distribution.*
Rhinoclavis bonneti Cossmann .	(a) *Clava bonneti* (Cossmann). (Gwadar stage of Mekran Coast.)
Euthriofusus inopinatus Cossmann.	(a) "*Clavilithes*" *verbeeki* (Martin). (L. Miocene to Pliocene; Java to Mekran Coast.)
Conus (*Leptoconus*) *aulacophorus* Cossmann.	(a) *Conus* (*Leptoconus*) *aulacophorus* Cossmann.
Conus (*Leptoconus*) *bonneti* Cossmann.	(a) *Conus* (*Leptoconus*) *bonneti* Cossmann. (Miocene of Burma, including Obogon.)
Conus (*Leptoconus*) *cosmetulus* Cossmann.	(a) *Conus* (*Leptoconus*) *cosmetulus* Cossmann.
Conus (*Dendroconus*) *figulinus* Linné.	(a) *Conus* (*Dendroconus*) *figulinus* Linné. (Recent.)
Conus (*Leptoconus*) *karikalensis* Cossmann.	(a) *Conus* (*Leptoconus*) *karikalensis* Cossmann.
Conus (*Lithoconus*) *litteratus* Linné	(a) *Conus* (*Lithoconus*) *litteratus* Linné. (L. Miocene to Recent; Timor to Cutch.)
Conus (*Lithoconus*) *maldivus* Hwass	(a) *Conus* (*Lithoconus*) *maldivus* Hwass. (Recent.)
Conus (*Leptoconus*) *hypermeces* Cossmann.	(b) *Conus* (*Lithoconus*) *ngavianus* Martin. (L. Miocene to Pliocene; Java, Sumatra, Timor.)
Conus (*Dendroconus*) *quercinus* Hwass.	(a) *Conus* (*Dendroconus*) *quercinus* Hwass. (Recent.)
Conus (*Chelyconus*) *subvimineus* Cossmann.	(a) *Conus* (*Leptoconus*) *vimineus* Reeve var. *subvimineus* Cossmann.
Drillia (*Crassispira*) *adelomorpha* Cossmann.	(a) *Crassispira adelomorpha* (Cossmann).
Drillia ferenuda Cossmann . .	(a) *Crassispira ferenuda* (Cossmann).
Drillia karikalensis Cossmann .	(a) *Crassispira karikalensis* (Cossmann)
Drillia sinensis Hinds . .	(a) *Crassispira sinensis* (Hinds). (Recent.)
Crucibulum (*Bicatillus*) *conulatum* Cossmann.	(a) *Crucibulum* (*Bicatillus*) *conulatum* Cossmann. (Also believed to occur in L. Miocene collections from the Arakan Coast.)
Cyllene varians Cossmann . .	(a) *Cyllene varians* Cossmann. (L. Pliocene/U. Miocene of Java.)
Melongena (*Pugilina*) *proteiformis* Cossmann.	(a) *Cymia sacellum* (Chemnitz). (Pliocene to Recent; Indo-Pacific.)
Rimella cancellata (Lamarck) .	(a) *Dientomochilus cancellatus* (Lamarck). (Pliocene to Recent; Java, Timor, Seran, Indo-Pacific.)
Rimella margaritae Cossmann .	(a) *Dientomochilus margaritae* (Cossmann).
Persona metableta Cossmann .	(a) *Distorsio reticulatum* (Linné) var. *cancellinum* (de Roissy).
Terebra (*Myurella*) *mariesi* A. Smith.	(a) *Duplicaria mariesi* (A. Smith). (Recent.)
Pirula reticulata Lamarck . .	(a) *Ficus reticulata* (Lamarck). (L. Miocene to Recent; Indo-Pacific to Europe.)
Fusus perplexus Adams . .	(a) *Fusinus perplexus* (Adams). (Recent.)

Original Determination.	*Present Determination and Distribution.*
Cryptospira (*Gibberula*) *cuneata* Cossmann.	(a) *Gibberula cuneata* (Cossmann).
Cryptospira (*Gibberula*) *glandina* (Vélain).	(a) *Gibberula glandina* (Vélain). (Recent.)
Cryptospira (*Gibberula*) *tectiformis* (Cossmann).	(a) *Gibberula* (*Closia* ?) *tectiformis* Cossmann.
Clathurella bicrenata Cossmann .	(a) *Glyphostoma bicrenata* (Cossmann).
Clathurella costicrenata Cossmann	(a) *Glyphostoma costicrenata* (Cossmann).
Clathurella karikalensis Cossmann	(a) *Glyphostoma karikalensis* (Cossmann).
Hemicerithium inopinatum Cossmann.	(a) *Hemicerithium inopinatum* Cossmann.
Drillia bonneti Cossmann . .	(a) *Kaweka bonneti* (Cossmann).
Vermetus javanus Martin . .	(a) *Lemintina javana* (Martin). (L. Miocene to Pliocene ; Assam, Java, Timor.)
Drillia (*Crassispira*) *quadricarinata* Cossmann.	(a) " *Mangelia* " *quadricarinata* (Cossmann).
Marginella (*Eratoidea*) *bonneti* Cossmann.	(a) *Marginella* (*Eratoidea*) *bonneti* Cossmann.
Marginella (*Eratoidea*) *karikalensis* Cossmann.	(a) *Marginella* (*Eratoidea*) *karikalensis* Cossmann.
Marginella (*Glabella*) *oligoptycha* Cossmann.	(a) *Marginella* (*Prunum*) *oligoptycha* Cossmann.
Mathildia bonneti Cossmann .	(a) *Mathilda bonneti* (Cossmann).
Eulima grandis A. Adams . .	(a) *Melanella grandis* (A. Adams). (Recent.)
Cancellaria (*Merica*) *asperella* Lamarck.	(a) *Merica asperella* (Lamarck). (Pliocene to Recent ; Java, Sumatra, Timor, Indo-Pacific.)
Cancellaria (*Merica*) *verbeeki* Martin.	(a) *Merica verbeeki* (Martin). (Obogon of Burma ; Pliocene of Java ; also believed to occur in L. Miocene collections from the Arakan Coast.)
Mitra (*Cancilla*) *circulata* Kiener .	(a) *Mitra* (*Tiara*) *circulata* Kiener. (Recent.)
Mitra (*Cancilla*) *flammea* Quoy .	(a) *Mitra* (*Tiara*) *flammea* Quoy. (U. Miocene to Recent ; Java, Sumatra, Timor, Seran, Borneo, Nias, Mekran Coast.)
Murex bonneti Cossmann . .	(a) *Murex* (*Tubicauda* ?) *bonneti* Cossmann.
Murex (*Muricopsis*) *diarti* Cossmann.	(a) *Muricopsis diarti* (Cossmann).
Hindsia tjemoroensis Martin .	(a) *Nassaria mekranica* (Vredenburg). (Talar stage of Mekran Coast.)
Nassa (*Hebra*) *bonneti* Cossmann .	(a) *Nassarius* (*Hebra*) *bonneti* (Cossmann).
Nassa (*Hinia*) *colpophora* Cossmann.	(a) *Nassarius* (*Hinia*) *colpophorus* (Cossmann).
Nassa (*Amycla*) *dimorpha* Cossmann.	(a) *Nassarius* (*Amyclina*) *dimorphus* (Cossmann).
Nassa ovum Cossmann, 1903 *non* Martin, 1883–7.	(a) *Nassarius francoindicus* (Martin).

Original Determination.	*Present Determination and Distribution.*
Nassa (*Niotha*) *gemmulata* Lamarck.	(a) *Nassarius* (*Niotha*) *gemmulatus* (Lamarck). (Pliocene to Recent ; Java, Sumatra, Seran, Indo-Pacific.)
Nassa (*Telasco*) *verbeeki* Martin .	(a) *Nassarius* (*Telasco*) *verbeeki* (Martin). (U. Miocene to Quaternary ; Java, Sumatra, Seran, Celebes.)
Natica forskali Chemnitz . .	(a) *Natica forskali* Chemnitz. (Recent ; Indo-Pacific.)
Natica marochiensis Gmelin var. *lurida* Philippi.	(a) *Natica marochiensis* Gmelin var. *lurida* Philippi. (Recent ; Indo-Pacific.)
Natica prosthenoglossa Cossmann	(a) *Natica* (*Naticarius*) *prosthenoglossa* Cossmann. (? Boka Bil of Assam ; also found in collections from the Kyaukkok of Burma.)
Natica rostalina Jenkins . .	(a) *Natica rostalina* Jenkins. (L. Miocene to Pliocene ; Java, Assam.)
Niso marmorata Sowerby . .	(a) *Niso marmorata* Sowerby. (Pliocene to Recent ; Java, Indo-Pacific.)
Oliva (*Neocylindrus*) *irisans* Lamarck.	(a) *Oliva* (*Neocylindrus*) *irisans* Lamarck. (Recent.)
Oliva (*Neocylindrus*) *mustellina* Lamarck.	(a) *Oliva* (*Neocylindrus*) *mustellina* Lamarck. (Talar stage of Mekran Coast ; Recent in Indo-Pacific.)
Olivancillaria (*Agaronia*) *acuminata* (Lamarck).	(a) *Olivancillaria* (*Anazola*) *acuminata* (Lamarck). (U. Miocene to Recent ; Java, Sumatra, Indo-Pacific.)
Oliva cheribonensis Martin . .	(a) *Olivancillaria gibbosa* (Born). (Pliocene to Recent ; Java, Indo-Pacific.)
Raphitoma mirostriata Cossmann .	(a) *Paraclathurella* (?) *mirostriata* (Cossmann).
Clavatula (*Perrona*) *unisulcata* Cossmann.	(a) *Perrona unisulcata* (Cossmann). (Mekran series of Mekran Coast.)
Cassis (*Casmaria*) *bonneti* Cossmann.	(a) *Phalium* (*Semicassis*) *bonneti* (Cossmann).
Semicassis (*Bezoardica*) *strigata* (Gmelin).	(a) *Phalium* (*Semicassis*) *sculptum* (J. de C. Sowerby). (Gaj of Cutch ; Miocene of Quilon.)
Phos macrostoma Cossmann .	(a) *Phos* (*Fax* ?) *macrostomus* Cossmann.
Pyramidella balteata (A. Adams) .	(a) *Plotia balteata* (A. Adams, in Sowerby). (Recent.)
Natica globosa (Chemnitz) . .	(a) *Polinices* (*Euspira*) *globosus* (Chemnitz). (L. Miocene to Recent ; common in Indo-Pacific.)
Natica (*Polynices*) *martini* Crossmann.	(a) *Polinices martini* (Cossmann).
Natica (*Mamma*) cf. *melanostoma* Gmelin.	(a) *Polinices melanostomus* (Gmelin). (L. Pliocene/U. Miocene of Java ; recent in Indo-Pacific.)
Turritella eudeli Cossmann . .	(a) *Protoma eudeli* (Cossmann).

Original Determination.	*Present Determination and Distribution.*
Atilia simplex (Martin) . .	(a) *Pterygia* (*Columbellopsis*) *simplex* (Martin). (U. Miocene to Pliocene ; Java, Sumatra.)
Actaeon (*Solidula*) *bonneti* Cossmann.	(a) *Pupa bonneti* (Cossmann).
Actaeon (*Solidula*) *solidulus* (Linné).	(a) *Pupa solidula* (Linné). (Recent ; Indo-Pacific.)
Ringicula bonneti Cossman . .	(a) *Ringicula* (*Ringiculella*) *bonneti* Cossmann.
Rissoina bonneti Cossman . .	(a) *Rissoina bonneti* Cossmann.
Atys (*Alicula*) *panaulax* Cossmann	(a) *Scaphander panaulax* (Cossmann).
Crepidula (*Siphopatella*) *subcentralis* Cossmann.	(a) *Sigapatella subcentralis* (Cossmann). (Gwadar stage of Mekran Coast.)
Stigmaulax aratulum Cossmann .	(a) *Sinum* (*Sigaretotrema*) *aratulum* (Cossmann).
Sigaretus bonneti Cossman . .	(a) *Sinum bonneti* (Cossmann).
Solariella amblygoniata Cossmann	(a) *Solariella amblygoniata* Cossmann.
Solariella distinguenda Cossmann .	(a) *Solariella distinguenda* Cossmann.
Solariella karikalensis Cossmann	(a) "*Solariella*" *karikalensis* Cossmann.
Solariella (?) *pachyzodes* Cossmann	(a) "*Solariella*" *pachyzodes* Cossmann
Solariella (?) *pachyzodes* Cossmann var. *bonneti* Cossmann.	(a) "*Solariella*" *pachyzodes* Cossmann var. *bonneti* Cossmann.
Strombus karikalensis Cossmann .	(a) *Strombus karikalensis* Cossmann.
Sveltia (*Aneurystoma*) *morgani* Cossmann.	(a) *Sveltia* (*Aneurystoma*) *morgani* Cossmann.
Syrnola karikalensis Cossmann .	(a) *Syrnola karikalensis* Cossmann.
Terebra (*Myurella*) *cingulifera* Lamarck.	(a) *Terebra* (*Myurella*) *cingulifera* Lamarck. (Recent ; Indo-Pacific.)
Terebra (*Myurella*) *continuicosta* Cossmann.	(a) *Terebra* (*Strioterebrum*) *continuicosta* Cossmann.
Terebra (*Myurella*) *cancellata* Quoy	(b) *Terebra* (*Strioterebrum*) *intermedia* Vredenburg. (Obogon and Kyaukkok of Burma.)
Terebra (*Myurella*) *cumingi* Deshayes (pars.).	(a) *Terebra* (*Strioterebrum*) *karikalensis* Vredenburg.
Terebra (*Myurella*) *cumingi* Deshayes (pars.).	(a) *Terebra* (*Strioterebrum*) *vredenburgi* Finlay. (Obogon and Kyaukkok of Burma ; Miocene of Java.)
Rostellaria fusus (Linné) . .	(a) *Tibia fusus* (Linné). (Pliocene to Recent ; Java, Indo-Pacific.)
Trigonostoma bonneti Cossmann .	(a) *Trigonostoma bonneti* Cossmann. (Kyaukkok of Burma.)
Trigonostoma crispatum (Sowerby)	(a) *Trigonostoma crispatum* (Sowerby). (Talar stage of Mekran Coast ; Pliocene of Java ; Recent in Indo-Pacific.)
Trigonostoma tjibaliungense (Martin).	(a) *Trigonostoma tjibaliungense* (Martin). (Pliocene of Java.)
Tudicula spirillus (Linné) . .	(a) *Tudicla spirilla* (Linné). (Recent in Indo-Pacific.)
Xenophora (*Tugurium*) *calculifera* (Reeve).	(a) *Tugurium calculiferum* (Reeve). (Pliocene to Recent ; Java, Indo-Pacific.)
Surcula javana (Linné) . .	(a) *Turricula javana* (Linné). (Recent ; Indo-Pacific.)

Original Determination.	*Present Determination and Distribution.*
Surcula punctata (Reeve) . .	(a) *Turricula nellii* (E. Smith). (Mekran series of Mekran Coast ; Recent in Indo-Pacific.)
Pleurotoma (*Hemipleurotoma*) *bonneti* Cossmann.	(a) *Turris* (*Gemmula*) *bonneti* (Cossmann). (Gaj of Cutch ; Obogon and Kyaukkok of Burma.)
Pleurotoma (*Hemipleurotoma*) *cingulifera* Lamarck.	(a) *Turris* (*Hemipleurotoma*) *cingulifera* (Lamarck). (Recent ; Indo-Pacific.)
Turritella djadjariensis Martin .	(a) *Turritella* (*Zaria*) *angulata* J. de C. Sowerby. (Oligocene to Quaternary ; abundant in Indo-Pacific.)
Turritella eucosmeta Cossmann .	(a) *Turritella* (*Haustator*) *eucosmeta* Cossmann.
Turritella trifunis Cossmann .	(a) *Turritella* (*Haustator*) *trifunis* Cossmann.
Typhis (*Typhinellus*) *tetragoniatus* Cossmann.	(a) *Typhis* (*Laevityphis*) *tetragoniatus* Cossmann.
Narica rhytidozodes Cossmann .	(a) *Vanikoro rhytidozodes* (Cossmann)
Turricula lirocostata Cossmann .	(a) *Vexillum* (*Costellaria*) *lirocostatum* (Cossmann).
Turbinella rapa Gmelin . .	(a) *Xancus pirum* (Linné). (Recent ; India.)
Murex (*Muricidea*) *infratabulatus* Cossmann.	(a) " *Xymenella* " *infratabulata* (Cossmann).
Raphitoma crenicostata Cossmann	(a) *Genus A crenicostata* (Cossmann).
Mangilia houdasi Cossmann. .	(a) *Genus B houdasi* (Cossmann).
? *Surcula streptopleura* Cossmann.	(a) *Genus C streptopleura* (Cossmann).
Nassa (*Hinia*) *karikalensis* Cossmann.	(a) *Genus D karikalensis* (Cossmanr).
Anadara (*Scapharca*) *bonneti* Cossmann.	(a) *Anadara* (*Scapharca*) *bonneti* Cossmann.
Anadara prope-oblonga Cossmann	(a) *Anadara craticulata* (Nyst) var. *birmanica* (Vredenburg). (Miocene of Burma, including Pyawbwe and Kyaukkok ; Boka Bil of Assam.)
Anadara ferruginea (Reeve) . .	(a) *Anadara ferruginea* (Reeve). (Pliocene to Recent ; Timor, Indo-Pacific.)
Anadara rectangularis Cossmann .	(a) *Anadara rectangularis* Cossmann.
Anadara tambacana (Martin) .	(a) *Anadara tambacana* (Martin). (U. Miocene and Pliocene of Java ; Gwadar stage of Mekran Coast.)
Arca (*Barbatia*) *bataviana* Martin .	(a) *Arcopsis bataviana* (Martin). (L. Miocene to Pliocene ; Burma, Assam, Java, Sumatra, Timor.)
Solenocurtus abbreviatus (Gould) .	(a) *Azorinus abbreviatus* (Gould). (Recent in Pacific.)
Phacoides (*Parvilucina*) *bonneti* Cossmann.	(a) *Cavilucina* (*Monitilora*) *bonneti* (Cossmann).
Aequipecten martini Cossmann .	(a) *Chlamys* (*Aequipecten*) *martini* (Cossmann).
Chlamys ickei Cossmann . .	(a) *Chlamys senatoria* (Gmelin). (M. Oligocene (Padaung) to Recent ; common in Indo-Pacific.)

Original Determination.	*Present Determination and Distribution.*
Aequipecten tjaringinensis (Martin)	(a) *Chlamys* (*Aequipecten*) *tjaringinensis* (Martin). (L. Miocene to Pliocene ; Java, Aroe Islands, New Guinea, Mekran Coast.)
Aequipecten tjaringinensis (Martin) var. *karikalensis* Cossmann.	(a) *Chlamys* (*Aequipecten*) *tjaringinensis* (Martin) var. *karikalensis* Cossmann.
Circe (*Circenita*) *tivelinoides* Cossmann.	(a) *Circe* (*Circenita*) *tivelinoides* Cossmann.
Chione (*Clausinella*) *karikalensis* Cossmann.	(a) *Clausinella karikalensis* (Cossmann). (Also found in L. Miocene collections from the Arakan Coast and Burma.)
? *Astarte* sp. Cossmann . .	(a) *Clementia papyracea* (Gray). (M. Eocene to Recent ; abundant in Indo-Pacific ; also in Austria.)
Corbula bonneti Cossmann . .	(a) *Corbula bonneti* Cossmann.
Corbula laterugata Cossmann .	(a) *Corbula laterugata* Cossmann. (Also found in Gaj collections from W. Pakistan.)
Corbula pachymorpha Cossmann .	(a) *Corbula* (*Varicorbula*) *pachymorpha* Cossmann.
Corbula scaphoides Hinds . .	(a) *Corbula* (*Varicorbula*) *scaphoides* Hinds. (U. Miocene to Recent ; Sumatra, Java, Timor, Indo-Pacific.)
Corbula socialis Martin . .	(a) *Corbula socialis* Martin. (L. Miocene to Pliocene ; Burma, Java, Assam, Sumatra, Timor, Seran, New Guinea.)
Crassatella (*Crassinella*) *bonneti* Cossmann (pars.).	(a) " *Crassatina* " *bonneti* (Cossmann).
Crassatella (*Crassinella*) *bonneti* Cossmann (pars.).	(a) " *Crassatina* " *bonneti* (Cossmann) var. *marwicki* Chavan.
Crassatella (*Crassinella*) *pachyrhytidea* Cossmann	(a) " *Crassatina* " *pachyrhytidea* (Cossmann).
Crassatella dimorphorugata Cossmann.	(a) " *Crassinella* " *radiata* (Sowerby). (Pliocene to Recent ; Java, Indo-Pacific. Also found in L. Miocene collections from the Arakan Coast.)
Barbatia martini Cossmann . .	(a) *Cucullaea martini* (Cossmann).
Cucullaea pectunculina Cossmann.	(a) *Cucullaea pectunculina* Cossmann.
Divaricella rapa Cossmann . .	(a) *Divaricella rapa* Cossmann.
Crassatella caudifera Cossmann .	(a) " *Eucrassatella* " *caudifera* (Cossmann).
Psammobia noetlingi Cossmann .	(a) *Gari noetlingi* (Cossmann).
Pectunculus (*Axinaea*) *bonneti* Cossmann.	(a) *Glycymeris bonneti* (Cossmann). (Also found in collections from the Boka Bil of the Arakan Coast, and from the Kyaukkok and Obogon of Burma.)
Pectunculus crenatocinctus Cossmann.	(a) *Glycymeris crenatocinctus* (Cossmann).
Cardium (*Loxocardium*) *karikalense* Cossmann.	(a) *Loxocardium karikalense* (Cossmann).
Here (*Pleurolucina*) *inopinata* Cossmann.	(a) *Lucina* (*Pleurolucina*) *inopinata* (Cossmann).

Original Determination.	*Present Determination and Distribution.*
Miltha ? martini Cossmann . .	(a) *Lucina martini* (Cossmann).
Macoma erycinoides Cossmann .	(a) *Macoma erycinoides* Cossmann. (Also found in the "Tipam sandstone" faunas of the Arakan Coast.)
Callista erycina (Linné) . .	(a) *Macrocallista* (*Costacallista*) *erycina* (Linné). (Miocene to Recent; Indo-Pacific and Mediterranean.)
Miocardia metavulgaris (Noetling)	(a) *Meiocardia metavulgaris* Noetling. (Pyawbwe stage of Burma.)
Nucula lunulicrenata Cossmann .	(a) *Nucula phayreiana* Noetling. (Miocene of Burma, including Kyaukkok and Pyawbwe; also found in the "Tipam sandstone" faunas of the Arakan Coast.)
Leda inaequirugata Cossmann .	(a) *Nuculana* (*Saccella*) *inaequirugata* (Cossmann).
Ostrea (*Alectryonia*) *junghuhni* Martin.	(a) *Ostrea* (*Lopha*) *hyotis* Linné. (Oligocene to Recent; abundant in the Indo-Pacific.)
Ostrea (*Cubitostrea*) *karikalensis* Cossmann.	(a) *Ostrea* (*Cubitostrea*) *karikalensis* Cossmann.
Aequipecten vexilloides Cossmann.	(a) *Pecten vexilloides* (Cossmann).
Phacoides micropteryx Cossmann .	(a) *Phacoides micropteryx* Cossmann.
Sunetta dautzenbergi Cossmann .	(a) *Sunetta dautzenbergi* Cossmann. (Recent in India; also found in L. Miocene and higher horizons in the Arakan Coast, and in L. and M. Miocene beds in Burma.)
Tellina (*Moerella*) *bonneti* Cossmann.	(a) *Tellina* (*Moerella*) *bonneti* Cossmann. (Also found in L. Miocene and higher horizons on the Arakan Coast, and in L. and M. Miocene beds in Burma.)
Cryptogramma semiradiatum Cossmann.	(a) *Timoclea semiradiata* (Cossmann).
Chione bataviana (Martin) *sec* Cossmann *non* Martin.	(a) *Timoclea* sp. A.
Cardium yokoyamai Cossmann .	(a) *Trachycardium yokoyamai* (Cossmann).
Venericardia bonneti Cossmann .	(a) *Venericardia bonneti* Cossmann.
Venericardia martini Cossmann .	(a) *Venericardia martini* Cossmann.
Venericardia oligopleura Cossmann	(a) *Venericardia oligopleura* Cossmann.
Venericardia phyletica Cossmann .	(a) *Venericardia phyletica* Cossmann.
Venericardia solitaria Cossmann .	(a) *Venericardia solitaria* Cossmann.
Cyprimeria nepotina Cossmann .	(a) *Genus E nepotina* (Cossmann).
Dentalium proteiforme Cossmann	(a) *Dentalium* (*Tesseracme*) *proteiforme* Cossmann.

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Micropalaeontological Research in European Upper Carboniferous Stratigraphy

By HELMUT BARTENSTEIN

(PLATE XII)

ABSTRACT

A synopsis is given of the most recent developments from micropalaeontological research on the coal-bearing Upper Carboniferous (Namurian C—Westphalian C) of Westphalia. The hope is expressed that a wider use of the technique of breaking down the mudstones into mud and isolating the fossils will, in conjunction with the important palaeontological results obtained in the English coal-basins, facilitate correlation between the Upper Carboniferous (Westphalian A to C) of England and Germany; also that the same technique will enable deep borings to be correlated in greater detail.

I. INTRODUCTION

THE recent work of Edwards and Stubblefield (1948) has refocused attention on the importance of utilizing the macro- and microfossils, in conjunction with lithological sequences, for detailed stratigraphical research on the Upper Carboniferous coal-bearing strata. By this means it was possible to establish correlations between neighbouring English coalfields and, in the case of two horizons and possibly others, with coal-basins in Belgium, Holland, and Westphalia.

These studies have an important bearing on research in the Upper Carboniferous of Germany, because in Westphalia the previous divisions based on macro-fossils (Text-fig. 1) have been reinforced by the completion of micropalaeontological researches, started in 1946 on the clay-grade sediments.

I am grateful to Dr. C. J. Stubblefield and to Mr. W. Edwards for their friendly services in the preparation and translation of this paper.

II. PREVIOUS RESULTS IN GERMANY

Work published between 1931 and 1934 (Ibrahim, Potonié, Ibrahim and Loose, Stach and Zerndt, Wicher) on the macrospores and microspores in certain coal seams produced some detailed stratigraphical conclusions in the Westphalian Upper Carboniferous. However, these researches were limited to the Westphalian B and C strata above the Katharina horizon, for in the earlier beds coalification was so advanced that no spores were obtainable. Recently such researches have been continued, using improved techniques.

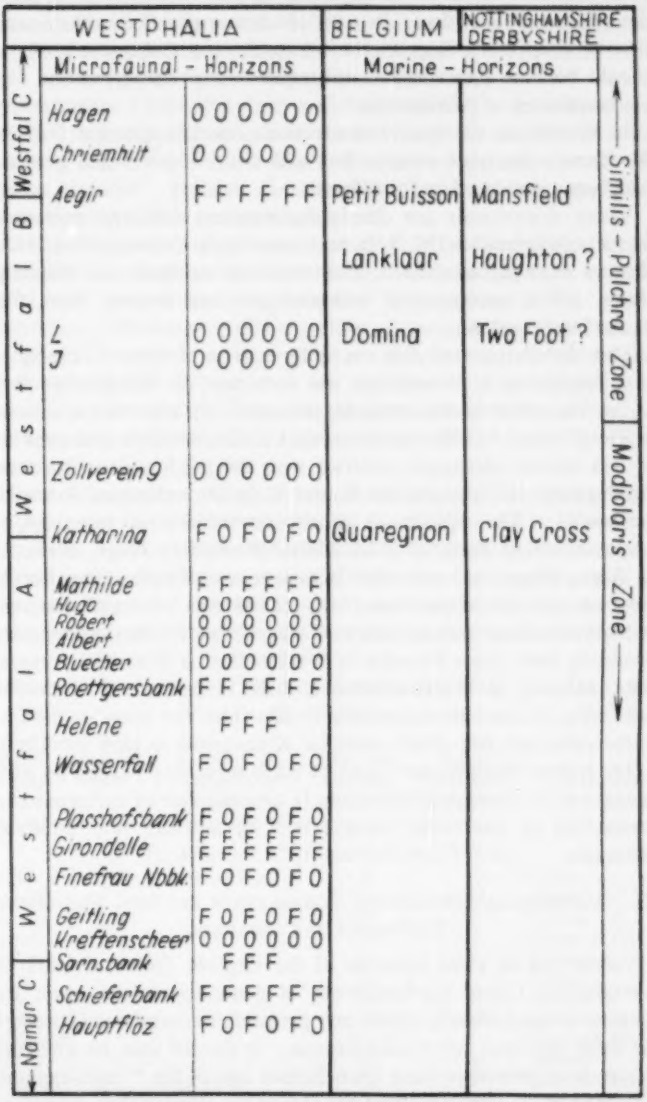
Systematic microfaunal studies have been confined to the mudstones (Bartenstein, 1948), using the following technique: The mudstone is broken into small fragments, heated for some minutes in

a water-solution containing about 12 per cent hydrogen peroxide (two parts of water to one of H_2O_2 of 35 per cent strength), and the resultant mud is poured into a sieve of 0·1 mm. mesh, through which

Westfal	C	Flammkohlen-Schichten	360m	Obere Flammkohlen-Sch.	138m
				Untere Flammkohlen-Sch.	222m
				Flöz Aegir	
	B	Gasflammkohlen-Schichten	368m	Obere Gasflammkohlen-Sch.	154m
				Flöz T (Bismarck)	
				Untere Gasflammkohlen-Sch.	214m
				Flöz L	
		Gaskohlen-Schichten	481m	Obere Gaskohlen-Sch.	206m
				Fl. Zollverein 1	
				Mittlere Gaskohlen-Sch.	140m
				Untere Gaskohlen-Sch.	135m
				Flöz Katharina	
	A	Fettkohlen-Schichten	630m	Obere Fettkohlen-Sch.	152m
				Flöz Hugo	
				Mittlere Fettkohlen-Sch.	230m
				Flöz Präsident	
				Untere Fettkohlen-Sch.	248m
				Fl. Plasshofsbank	
		Esskohlen-Schichten	417m	Obere Esskohlen-Sch.	245m
				Untere Esskohlen-Sch.	172m
				Fl. Sarnsbank	
Namur	C	Magerkohlen-Schichten	632m	Obere Magerkohlen-Sch.	292m
				Flöz Neuflöz	
				Untere Magerkohlen-Sch.	340m
			2888m		2888m

TEXT-FIG. 1.—Generalized section of the coal-bearing strata in the Ruhr Coalfield. Marine bands are indicated by a conventional sign, and the dominance of ostracods about the Hugo Coal is also indicated. Thicknesses are given in metres.

passes the finest mud and sand, leaving on the sieve all fossils above 0·1 mm. diameter. This "mud-method" obviates the necessity of relying on the fauna visible on polished rock-faces and thin sections,


WESTPHALIA
BELGIUM
NOTTINGHAMSHIRE DERBYSHIRE
Microfaunal - Horizons
Marine - Horizons
Namur C
Westfal A
Westfal B
Westfal C
Hagen 0 0 0 0 0 0
Chriemhilt 0 0 0 0 0 0
Aegir F F F F F F
Petit Buisson
Mansfield
Lanklaar
Haughton ?
L 0 0 0 0 0 0
J 0 0 0 0 0 0
Domina
Two Foot ?
Zollverein 9 0 0 0 0 0 0
Katharina F 0 F 0 F 0
Quaregnon
Clay Cross
Mathilde F F F F F F
Hugo 0 0 0 0 0 0
Robert 0 0 0 0 0 0
Albert 0 0 0 0 0 0
Bluecher 0 0 0 0 0 0
Roettgersbank F F F F F F
Helene F F F
Wasserfall F 0 F 0 F 0
Plasshofsbank F 0 F 0 F 0
Girondelle F F F F F F
Finefrau Nbbk F 0 F 0 F 0
Geitling F 0 F 0 F 0
Kreftenscheer 0 0 0 0 0 0
Sarnsbank F F F
Schieferbank F F F F F F
Hauptflöz F 0 F 0 F 0
Similis - Pulchra Zone
Modiolaris Zone

TEXT-FIG. 2.—Microfaunal horizons developed in coal-bearing strata in the Ruhr Coalfield, and comparisons with marine horizons in Belgium and Nottinghamshire–Derbyshire. F, foraminifera ; O, ostracoda.

or as impressions on bedding-planes ; it thus promotes more efficient detection and saves time. It is the customary practice in the examination of deep oil-borings in the Mesozoic and Cainozoic rocks, and should become customary in subsequent deep borings in the Upper Carboniferous of Westphalia.

In Westphalia the first results indicate microfaunas not only from the known marine horizons, but also from zones which previously had been considered unfossiliferous.

These microfossils are chiefly foraminifera (notably agglutinated forms) and ostracods (Pl. XII), and more rarely Echinoderm and Holothurian remains, conodonts, and immature mollusca and brachiopod shells. Not uncommonly well-preserved macrospores were found in the mud-residues.

The distribution of the microfauna is as follows (Text-fig. 2) : in Westphalian A foraminifera are dominant, in Westphalian B and C, on the other hand, ostracods abound. Strong marine invasions of Westphalian A (with marine or brackish foraminifera and some more or less marine ostracods) contrast with the predominant fresh-water development of Westphalian B and C (with undoubted fresh-water ostracods). The abundance of the microfauna is very variable : whereas certain horizons (Girondelle, Wasserfall, Hugo, Katharina, L, Aegir, Hagen) are consistently rich in microfossils, other horizons are poor and sometimes free from microfossils. Nevertheless, these microfaunas have already indicated that Upper Carboniferous marine invasions were more frequent in Westphalian A than had previously been realized. In Westphalian B and the lower part of C there is a possibility of some stratigraphical results from the study of the fresh-water ostracods (on which material Kummerow is now working).

The higher Westphalian C and D up to now have yielded no microfauna, neither foraminifera (which, in consequence of the pronounced sweetening of the water, should here be lacking) nor freshwater ostracods.

III. Micropalaeontological Correlation between English and Continental Coalfields

Correlation of some horizons of the English, Dutch, Belgian, and Westphalian Upper Carboniferous is generally agreed upon from evidence of macrofossils, others may probably be correlated (Text-fig. 2), for these horizons carry microfaunas ; it should thus be interesting to see developments arising from further use of the " mud-method ". The application of this method has shown the Westphalian microfauna to be richer than was previously supposed, and the method has the advantage of isolating and preserving the microfossils in a complete condition, an important consideration in systematic palaeontology.

As yet no micropalaeontological research has been published from the coalfields of Belgium and Holland which adjoin Westphalia and these might supply connecting links with the English succession, which appears to be rich in macro- and microfossils.

Nevertheless, I hope that these methods developed in the laboratories of the oil industry will be applied as in Westphalia, so also in other European countries, for it is likely that many new microfossils will thus be revealed. Perhaps also there will result further correlation where at present little or none exists.

The need for such comparisons is great, since the Westphalian Upper Carboniferous shows a very monotonous microfauna, poor in both genera and species (only agglutinated foraminifera of the genera *Ammodiscus*, *Glomospira*, *Glomospirella*, *Hyperammina*, and *Thuramminoides*); furthermore, according to Kummerow, the freshwater ostracods collected fall into but few species. It is anticipated from the variety of genera and species already described from Belgium, Holland, and England, that richer fauna will be found in those countries.

These micropalaeontological researches are particularly necessary at the present time, when deep boring for coal and oil is in progress and where detailed stratigraphical knowledge is being sought which only micropalaeontology can provide. The cores from such borings are frequently small and may fail to yield macrofossils; so that the study of the microfossils by breaking the core into mud is therefore desirable.

APPENDIX SHOWING SCOPE OF WORK ON WHICH THE PAPER IS BASED

Horizon (Clay-grade sediments above seam named).	*Previous description of roof-strata.*	*No. of samples examined.*	*No. of localities sampled.*	*Micro-fossil contents.*
	WESTPHALIAN C (*Flammkohlen-Schichten*)			
Loki	non-marine	9	2	Spores
Kobold	"	15	2	Spores
Iduna	"	30	2	Spores
Hagen	"	31	6	Spores & Ostr.[1]
Gudrun	"	21	3	Spores
Freya	"	22	3	Spores
Erda	"	15	2	Spores
Donar	"	8	3	Spores
Chriemhilt	"	13	5	Spores & Ostr.
Baldur	"	18	4	Spores
Aegir	marine	42	15	Spores, forams., & Ostr.
		224	47	

[1] The following abbreviations are used in this table :—Forams. = Foraminifera ; Moll. = Mollusca ; occ. = occasionally ; Ostr. = Ostracods.

Horizon (Clay-grade sediments above seam named).	*Previous description of roof-strata.*	*No. of samples examined.*	*No. of localities sampled.*	*Micro-fossil contents.*
WESTPHALIAN B (*Gasflammkohlen-schichten*)				
Y	non-marine	3	1	Nil
X	"	2	1	Nil
W	"	2	1	Nil
V	"	12	3	Spores
U	"	4	1	Nil
T (Bismarck)	"	12	4	Spores
S	"	5	3	Spores
R	"	4	2	Nil
Q	"	5	2	Nil
P	"	9	5	Spores
O	"	6	4	Nil
N	"	8	4	Spores
M	"	11	8	Nil
L (Domina)	brackish	46	17	Spores & Ostr.
		129	56	
WESTPHALIAN B (*Gaskohlen-schichten*)				
K	non-marine	4	3	Spores
J	"	11	2	Ostr. (occ.)
H	"	6	3	Nil
G	"	3	1	Nil
F	"	3	2	Nil
E	"	4	3	Spores
D	"	2	2	Nil
C	"	5	2	Nil
B	"	6	3	Nil
A	"	6	2	Nil
Zollverein 1	"	8	4	Spores
" 2	"	9	4	Spores
" 3	"	5	4	Spores
" 4	"	6	4	Nil
" 5	"	3	3	Nil
" 6	"	2	2	Nil
" 7	"	6	4	Nil
" 8	"	3	3	Nil
" 9	"	22	6	Ostr. (occ.)
Laura, Victoria	"	12	5	Nil
Katharina	marine	66	19	Moll., forams., Ostr.
		192	81	
WESTPHALIAN A (*Fettkohlen-schichten*)				
Hermann	non-marine	2	1	Nil
Gustav	"	2	1	Nil
Gretchen	"	5	2	Nil
Anna	"	3	2	Ostr. (occ.)
Matthias	"	4	2	Nil
Mathilde	"	9	3	Forams.
Hugo	"	30	13	Ostr.
Robert	"	5	2	Ostr. (occ.)
Albert	"	4	4	Ostr. (occ.)
Wellington	"	5	2	Nil

Horizon (Clay-grade sediments above seam named).	*Previous description of roof-strata.*	*No. of samples examined.*	*No. of localities sampled.*	*Micro-fossil contents.*
WESTPHALIAN A (*Fettkohlen-schichten*) (contd.)				
Karl	non-marine	7	2	Nil
Bluecher	"	10	4	Ostr. (occ.)
Ida	"	8	3	Nil
Ernestine	"	3	3	Nil
Roettgersbank	"	12	4	Forams. & Ostr.
Wilhelm	"	4	3	Nil
Johann	"	7	2	Nil
Praesident	"	8	4	Nil
Helene	"	13	5	Forams. (occ.)
Luise	"	8	3	Nil
Karoline	"	5	5	Nil
Angelika	"	4	2	Nil
Dickebank	"	8	5	Nil
Duennebank	"	7	3	Nil
Wasserfall	marine	34	14	Forams. & Ostr.
Sonnenschein	non-marine	8	5	Nil
Schoettelchen	"	10	2	Nil
Plasshofsbank	marine	10	4	Forams. & Ostr.
		235	105	
WESTPHALIAN A (*Esskohlen-schichten*)				
Girondelle 9	brackish	6	6	Nil
" 8	"	6	6	Nil
" 7	"	5	5	Forams.
" 6	"	4	4	Forams.
" 5	non-marine	5	5	Forams. (occ.)
" 4	"	4	4	Forams. (occ.)
" 3	"	6	5	Forams. (occ.)
" 2	brackish	5	4	Forams.
" 1	"	4	4	Forams.
Finefrau-Nebenbank	marine	24	13	Forams. & Ostr.
Finefrau	non-marine	16	8	Nil
Geitling 2–3	brackish	18	8	Forams. & Ostr.
Geitling 1	non-marine	8	4	Nil
Kreftenscheer 2	brackish	14	8	Ostr. (occ.)
" 1	non-marine	8	4	Nil
Mausegatt	"	20	5	Nil
Sarnsbank	marine	27	8	Moll. & occ. Forams.
		180	101	
NAMURIAN C (*Magerkohlen-schichten*)				
Sarnsbanksgen	non-marine	2	2	Nil
Schieferbank	marine	13	5	Forams. & Ostr.
Hauptfloez	part-marine	14	7	Moll., Forams.
Wasserbank	non-marine	11	4	Nil
Dreckbank	"	2	1	Nil
Neufloez	"	9	4	Nil
Hinnebecke	part-marine	5	2	? Ostr.
Besserdich	non-marine	2	2	Nil
Sengsbank	"	—	—	Nil
		58	27	

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EXPLANATION OF PLATE

A. Foraminifera from the Aegir Marine Band. × 35. *Hyperammina* sp. and *Ammodiscus* sp.

B. Foraminifera from the Wasserfall Marine Band. × 35. *Ammodiscus* sp.

C. Immature shells mainly mollusca from the Katharina Marine Band. × 35.

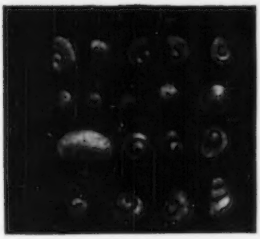
D. Foraminifera from the Schieferbank Marine Band. × 35. *Hyperammina* sp.

E. Ostracoda from some marine and non-marine bands. × 25.

1. *Carbonita tenuis* Kummerow from the Hagen non-marine Band.
2. *Macrocypris* ? *bartensteini* Kummerow from the Chriemhilt 1 non-marine Band.
3. " Ostracode a " (Kummerow) from the Hugo non-marine Band.
4. Cf. *Carbonita tenuis* Kummerow from the Robert non-marine Band.
5. *Limnoprimitia arcuata* (Bean) and *Limnoprimitia* sp. from the Wasserfall marine Band.
6. *Limnoprimitia robusta* Kummerow from the Kreftenscheer II ? Marine Band.

A × 35

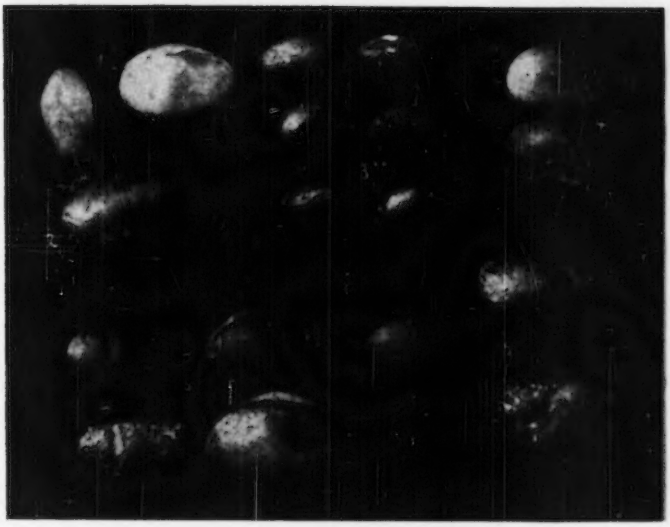
B × 35



C × 35

D × 35

E × 25



UPPER CARBONIFEROUS MICROFOSSILS.

Marine Bands in the Coal Measures of Britain and Germany

By C. J. STUBBLEFIELD and W. EDWARDS

DR. BARTENSTEIN'S results show considerable progress in the recognition of marine horizons within the belt of Westphalian strata lying between the Sarnsbank Coal *Gastrioceras subcrenatum* Marine Band and the Katharina *Anthracoceras vanderbeckei* Marine Band. Kukuk (1938, pp. 166–171) recognized in this stratal belt but twelve marine or *Lingula* horizons, whereas the author from his foraminiferal finds in the same strata adds evidence of six more marine incursions in Westphalia.

Current research in the Yorkshire, Nottinghamshire, and Derbyshire Coalfield indicates, so far, but six such incursions despite careful searching of cored borings ; in the opinion of the writers it is doubtful whether the improved collecting technique advocated by Dr. Bartenstein would greatly increase this number.

It is noteworthy that between the Westphalian equivalents of the Clay Cross and Mansfield marine bands the author's researches have yielded no foraminifera except at those two horizons, nor have such been found in the strata overlying the Aegir or supposed equivalent of the Mansfield Marine Band. In the Nottinghamshire–Derbyshire Coalfield, on the other hand, it has been shown that there is evidence of eight marine incursions above that of the Clay Cross Marine Band (Edwards and Stubblefield, 1948, p. 211).

The generalization seems to be warranted, therefore, that the continuance into Westphalian A times of Namurian C or fairly typical Millstone Grit marine-band conditions was more prolonged in Westphalia than in Britain ; that is, the amplitude of rhythmic sedimentation was then such as to cause very frequent depressions below sea-level. In East Britain this tendency operated fairly frequently during Clay Cross Marine Band times and then ceased until Two-Foot Marine Band times when there started frequent repetition of marine invasions lasting some time after the Mansfield Marine deposition. In Westphalia, however, the fossiliferous sediments seem to indicate no such signs except at the L (= Domina) [1] and Aegir horizons, so that it may be concluded that the extreme marine impetus has moved westwards before its final cessation in the West European Coal Measures at the close of the Similis-Pulchra zone.

[1] Where Kukuk (1938, pp. 181, 184) recorded *Lingula*.

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Note on the Age of the Rocks on the East Side of Newport Bay, Pembrokeshire

By J. MYERS

ABSTRACT

Graptolites found on the east side of Newport Bay, Pembrokeshire, support the original interpretation of the 1857 edition of the one-inch geological map of the area that the rocks there are of Ordovician age and not Silurian as shown in more recent maps.

ON the 1 in. geological map of the Newport area in Pembrokeshire (Sheet 40—May, 1857) the rocks on the east side of Newport Bay are classed as Llandeilo in age. Keeping (1882) found graptolites too badly preserved for precise identification in the cliff south of Pen Pistill, but he thought that they indicated the age of the rocks as being either Llandeilo or Bala. Professor Lapworth had examined the graptolites and had suggested they were species of *Diplograptus* and *Climacograptus*, but could not say if they were of Lower Llandovery, Llandeilo, or Arenig age.

F. R. C. Reed (1895), in his paper on the Fishguard region, marked Dinas Island rocks as of Llandovery age. The south side of Newport Bay was shown to be occupied by Llandeilo and Bala rocks, but he made no attempt to assess the age of the rocks on the east side of the Bay. In the text (1895, p. 193) he expressed a doubt as to the Llandovery age of the Dinas Island Beds.

M. P. Latter (1925) in a study of the Teifi region had obtained in the shore south-east of Pen-y-Bal, Newport Bay, specimens of *Cryptograptus tricornis* (Carruthers) and *Orthograptus truncatus* var. *intermedius* Elles and Wood. Near Ceibwr Bay he found the former along with *Mesograptus multidens* Elles and Wood. Latter says that these fossils and others found elsewhere in the region suggested a likely gradual rise in sequence as the rocks are traced north-eastwards from Newport to Cardigan.

In spite of these facts the geological map of the British Isles (1 in. rep. 25 miles), published in 1938, shows Silurian rocks on Dinas Island and on the east side of Newport Bay. Challinor (1927) has drawn attention to similar errors on the ¼ in. geological map.

It should, however, be noted that the area in question is indicated as Ordovician on the Geological Survey 10 in. to the mile map (1948).

The matter may now be carried a stage further in support of the Ordovician age of the Newport Bay rocks because of the chance finding of moderately well preserved graptolites in August, 1947, in a band about 6 inches wide in vertical shales in the cliffs about 460 yards south of Pen Pistill. About twenty-five specimens were

submitted to the Geological Survey where, through the kindness of Mr. W. H. C. Ramsbottom, they were carefully examined. The report received stated that the graptolites made " an interesting and unusual assemblage ". They comprised the following :—

Diplograptus [*Mesograptus*] sp.
Diplograptus [*Mesograptus*] cf. *multidens* Elles and Wood.
Glyptograptus cf. *siccatus* Elles and Wood.
Glyptograptus cf. *euglyphus* Lapworth.
Amplexograptus cf. *arctus* Elles and Wood.

The report continues, " The horizon is not easy to tell precisely, but appears to be somewhere about the *Glyptograptus teretiusculus-Nemagraptus gracilis* boundary or a little higher. The lower horizon is suggested by *arctus* and *euglyphus*, whilst *siccatus* and *Mesograptus* would indicate a *gracilis* horizon."

A representative collection of these graptolites has been presented to the Geological Survey. My thanks are due to both Mr. Ramsbottom and Mr. S. W. Hester for their help and to Mr. J. Challinor for drawing my attention to two papers which refer to the region and for suggesting alterations in the original draft of this paper.

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Two Early-named Valid Species of English Upper Jurassic Ammonites

By W. J. Arkell

(PLATE XIII)

Abstract

Perisphinctes listeri (de Haan), 1825, from the Corallian Beds, and *Titanites cingulatus* (de Haan), 1825, from the Portland Beds, are valid species that have been overlooked. The original figures on which they were based are reproduced.

THE purpose of this note is to draw attention to and place on record in more accessible form two valid figured species of ammonites which appear to have been overlooked for a century and a quarter.

Planites listeri de Haan (1825, p. 93). Reference to and description based on Lister (1685, Tab. 1045). Lister's figure is an ink drawing nearly a foot across, depicting a large Upper Oxfordian *Perisphinctes* from the Corallian Beds of Nunnington, Yorkshire. Diameter of original stated to be 13 inches. Dr. Vernon Wilson informs me that large casts of this general character are not uncommon in the Urchin Beds thereabouts and generally find their way on to rockeries. "There is no reason why this specimen should not have come from one of the many large and small quarries in these oolites on the Cauklass promontory, in that part of it west of East Ness as far as the Nunnington cutting." He suggests that the pitting of the surface may be due to action of rootlets and humic acid.

The characters shown in the drawing do not agree with any other described species. The fewness of the ribs on the inner whorls and their very gradual decrease in density of spacing are only comparable with the subgenus *Arisphinctes* and with *P.* (*A.*) *maximus* (Young and Bird) (1828); but even that has far more ribs on the inner whorls, and its venter becomes smooth and broadly rounded long before the stage at which the venter of *P. listeri* is shown as still coarsely-ribbed and flat. The venter and the forward inclination and wide spacing of the primary ribs on the last quarter whorl in fact are not those of an *Arisphinctes* but of a *Perisphinctes sensu stricto* like *P. parandieri* de Loriol. *P. parandieri* and all other known species are ruled out by their much more densely ribbed umbilical whorls and the relatively sudden change to more widely-spaced primaries on the last whorl.

It is to be hoped that someone with opportunities to collect in the Nunnington district of Yorkshire will keep a look out for what may be an interesting new form.

Planites cingulatus de Haan (1825, p. 93). Reference to and description based on Lister (1685, Tab. 1046). On his p. 88, de Haan cited

Lister's figure in the synonymy of *Ammonites giganteus* Sowerby, but later apparently he changed his mind. The figure is also an ink drawing nearly a foot across. No locality is given, but the drawing obviously represents a *Titanites* from the Portland Beds and it gives the impression of accuracy. The special characters are extremely evolute coiling and scarcity of biplicate ribs. On the outer whorl all the ribs but 7 are shown as simple. This is probably an exaggeration, but any species with regular and conspicuous biplication or trifurcation of the ribbing is ruled out.

Any of the Portlandian outcrops could have produced the ammonite, but in the seventeenth century the Swindon quarries probably were not sufficiently developed. Of the many Portlandian ammonites figured by Buckman, *T. megasthenes* (1922, pl. cccv) has perhaps the most suggestive ribbing but is too involute. *T. pachymeres* (1925, pl. dxcii) is evolute and has somewhat obscurely-branching ribbing with many simple ribs. Lister's figure and de Haan's name should be borne in mind when the English Portlandian perisphinctids come to be monographed.

De Haan in his book made a number of other new species, based upon unfigured specimens in the Royal Museum in Amsterdam. These cannot be identified until types are figured. There is only one other new Jurassic species based on a bibliographical reference, namely *Planites knorrianus* de Haan (1825, p. 94), sp. nov. for Knorr, vol. i, Tab. xxxvii, fig. 2. This is a *Lytoceras* from Boll, Swabia, and judging by other ammonites figured with it on similar pieces of shale is Toarcian.

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EXPLANATION OF PLATE

Titanites cingulatus (de Haan) (right)

Perisphinctes listeri (de Haan) (left)

The original figures reproduced, much reduced, from Lister, 1685. (× ¼)

PERISPHINCTES LISTERI (DE HAAN) AND *TITANITES CINGULATUS* (DE HAAN).

The Nomenclature of Lower Carboniferous "Reef" Limestones in the North of England

By Geoffrey Bond

Abstract

Various ways in which Lower Carboniferous reef limestones have accumulated are described, and terms defining them are introduced. Regional sedimentation, lithology, structure, fauna, and erosion history are kept separate in the discussion. The reef limestones of Northern England are briefly reviewed in the light of this classification.

THE literature on the Lower Carboniferous rocks of the North of England has contained many references to "reef"-limestones since Tiddeman (1892) first coined the term "knoll-reef" (or reef-knoll) nearly sixty years ago. The type area for reef-knolls is the Cracoe district of Yorkshire. However, there has been much confusion in the literature caused by the ill-defined use of the terms "reef" and "knoll" and particularly by the application of the combined word "reef-knoll". It seems that these words and the areas to which they are applied are a constant source of controversy and misunderstanding. It is now clear that there are several types represented in the various "reefs" and that they cannot all be forced into any one explanation of their origin. From observations in Derbyshire and Yorkshire it seems to the writer that at least some of the difficulties could be overcome if a system of nomenclature could be devised which would describe the various types of structures and deposits so that ambiguity was eliminated.

The main cause of confusion arises from the failure to differentiate between terms which describe sedimentation and those which describe sediments. A further distinction is necessary to avoid the use of the purely topographic word *knoll* in connection with "reef" sediments. These have a tendency to be found where knoll topography is developed in certain facies belts, but not all knolls contain reef limestones, and not all reef limestones form knolls.

The use of the word "reef" itself could be questioned. Cumings (1932) discussed its definition, and quoted from Murray's Dictionary that it was "a narrow ridge or chain or rocks, shingle, or sand lying at or near the surface of the water". The "reef" limestones of the north of England yield abundant evidence that they were formed in shallow water, and sometimes show that emergence took place. Some of them seem to have formed long, narrow ridges, and as they show evidence that they were formed in shallow water the word reef would be permissible as a palaeogeographic term in describing them, so long as no biological or structural significance is implied. They are certainly

not coral reefs, and cannot be compared with present-day fringing or barrier reefs, or with those of the Jurassic described by Arkell (1933). Some of them may have been bryozoan reefs. There are mound-like features inside the main barrier reef off the Australian Coast which bear some resemblance in shape to a Tiddeman reef-knoll, but they are not strictly comparable. The term "chapeiro" seems to have priority for upstanding masses of organic rock, but as such structures are typically stack-like in form and quite unlike the Carboniferous reefs, they need not be further considered here.

In the discussion below the following factors are involved and must be clearly separated.

(1) Sedimentation and sediments.

(2) Fauna.

(3) Post-depositional disturbances due to folding, faulting, and erosion.

(4) Topography—fossil and recent.

(1) Sedimentation

The problems involved under sedimentation are twofold, and concern the relationship of reefs to the regional sedimentation and the manner in which they were locally deposited. Limestones of "reef" facies are found mainly in areas separating two contrasted types of sedimentation. These are the well-known basin and massif (or block) facies. Their existence implies differential stability of the sub-Carboniferous floor. Since a distinctive facies is found along the belt separating them and may involve several hundred feet of sediments, a special term is required for it, and *marginal* is suggested as more suitable than *transitional*. The rocks in these belts are not transitional in character between the shales-and-limestone facies of the basin and the pure fragmental limestones of the block. They occur at the edge of the block area of sedimentation, and are best regarded as belonging to the block rather than to the basin. Certain reef limestones may have originated within the basin areas due to local shallowing, and the term *basinal* suggested by Hudson is appropriate.

The second part of the problem of sedimentation involves the manner of accumulation of the sediments within these facies belts. It is essential that the terms used to describe the modes of accumulation (sedimentation) should be kept distinct from those which describe the lithology of the resulting sediments; and that neither set should be confounded with words which have a topographic or structural meaning.

To illustrate the various types involved, sections are given (Text-figs. 1–4) which, though treated diagrammatically, are based on various parts of the Castleton, Cracoe, Malham, and Scaleber marginal belts.

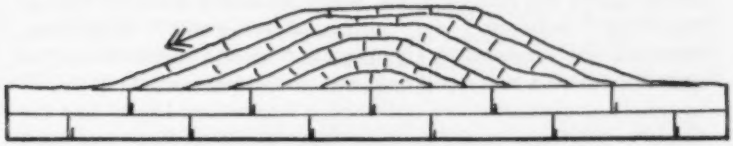
Terms Describing Sedimentation

(*a*) *Reef-knolls* (*or knoll-reefs*).

Tiddeman (op. cit.) had one particular mode of accumulation in mind when he used this term. He visualized a reef-knoll as a discrete accumulation of organic debris growing as a mound of original deposition upon the sea floor. He first used the term to describe the Cracoe knolls in Yorkshire, but it is doubtful if it can be applied to any of them in the sense in which he intended it.

It would be better, therefore, if the term could be abandoned, since it does not apply to the "type". However, it has become so firmly established in the European literature that it can hardly be eliminated now. If it is to be used it must only be in the strict sense for which it was intended by Tiddeman.

Such knolls should consist only of material deposited in the way Tiddeman described and the dips, being quaquaversal, would indicate their nature. They are dips of original deposition. To distinguish them



TEXT-FIG. 1.—Simplified section through a true Reef-knoll.

from dips produced later by earth movement a special symbol on the map would be an advantage, and it is suggested that a double-headed arrow could be used for the purpose.

A section through a true reef-knoll would give the appearance of Text-fig. 1. It would probably be exceedingly complex in detail, with many beds lenticular, and often truncated by local accidents of erosion during its growth, since the summit was supposed by Tiddeman to be near sea-level and occasionally exposed to wave and even wind action. The only way such a mound could reach any great height would be by the continued, though probably intermittent, subsidence of its floor. At least in the Craven marginal belt, true reef-knolls are conspicuously absent in rocks up to D_2 age.

The growth of such mounds implies that some form of levelling up was necessary before normally bedded sediments could again accumulate.

Although reef-knolls on a large scale are not to be found in the Cracoe district itself, W. W. Black (1949) has recently found such structures in the Middle Limestone of the Yoredale Series, just north of Grassington. They are only a few feet high, but are true reef-knolls

in miniature. In this case the surface was levelled up again by the accumulation of more limestone, which arched gently over the mounds until some thickness had been achieved, when normal bedding again resulted. The limestone mounds have been re-exposed more or less in their original state, since they were covered by brashy crinoidal limestone which is more easily removed by erosion than the material of the underlying mound.

The term " bioherm " was used by Cumings (1929) for structures which he defined as . . . " consisting of any dome-like, mound-like, lens-like, or otherwise circumscribed mass built exclusively or mainly by sedentary organisms such as corals, stromatoporoids, algae, brachiopods, molluscs, crinoids, etc., and enclosed in normal rock of different lithological character ".

The term has not been widely adopted by geologists interested in the Lower Carboniferous " reefs " of this country. In essence the definition is that of Tiddeman's reef-knoll, which has considerable priority. Furthermore, it has been used as a foundation for such terms as *hermatobiolith* and *hermatopelago*, which are merely awkward ways of describing " reef-rock " and " group of reef-knolls " respectively. *Biostrome* was suggested by Cumings for " bedded structures such as shell beds, crinoid beds, coral beds, etc., consisting of and built mainly by sedentary organisms and not swelling into mound-like or lens-like forms ". This term merely groups together the lithological types listed without giving any of them a clearer meaning. To introduce the above terms into discussions of our Lower Carboniferous " reefs " would seem to increase confusion rather than remove it.

Arkell (1933, p. 615) has dealt with this problem, and shown by two paragraphs of description that simple terms can be just as precise.

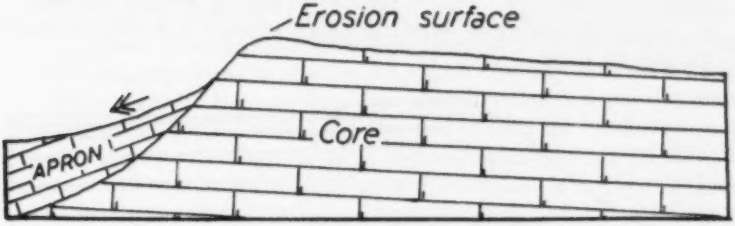
(*b*) *Apron-reefs.*

This term, suggested by Hudson, aptly describes another mode of accumulation. In this case a scarp abruptly terminates one series of limestones, and a scree of limestone material lies with pronounced discordance across the eroded edges of the older series.

Since the scarps appear to be fault or fault-line scarps, their existence does not necessarily imply a long time interval between the deposition of the rocks which compose them and the accumulation of the apron. A section across such a structure is given in Text-fig. 2.

It consists of three parts, a *core* of older rocks, which may be bedded sediments of massif or marginal facies, or of the type described below as unbedded reef limestone, an *erosion surface*, and an *apron* of later limestone. This may consist of angular material derived from the core, freshly accumulated sediment, or a combination of both. The dips in the apron are original and have a maximum angle of about 40° under water.

To apply the term " reef-knoll " to any part of such a structure would be misleading, and would not even be justified if its subsequent erosion history had shaped it into a knoll form. Apron-reef seems well suited to describe such beds plastered on to a slope, and the double-headed arrow could usefully be employed in mapping them. Structures of this kind occur in the Castleton district of Derbyshire, where they have been described by Shirley and Horsfield (1940), and to a lesser extent at Malham and Cracoe, in the Craven district of Yorkshire. This mode of accumulation was visualized long ago by Mojsisovics (1879, p. 169), who gave a diagram of such a structure in South Tyrol. Although his interpretation has since been criticized, there is little doubt that he had this type in mind.



TEXT-FIG. 2.—The relationship of apron-reef deposits to the erosion surface and core of older rocks.

(*c*) *Flat-reefs.*

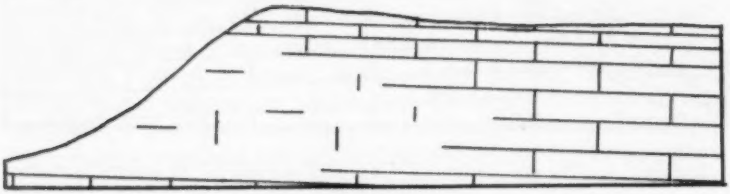
As far as the writer is aware this is a new term. It is intended to describe a mode of deposition leading to the accumulation of large spreads of more or less horizontally bedded limestones, which show by their fauna that they belong to the reef facies. It is not synonymous with the term biostrome (which has been no more popular than bioherm in this country) since the rocks are not necessarily composed mainly of organic remains, although there may be masses of shell beds included in them. The upper division at Swindon quarry, in the Cracoe Knolls, would fall into this category. It is rich in fossils, but is mostly composed of grain limestones. They are no longer horizontal, but their dips are tectonic, not original.

A flat-reef is a mode of sedimentation which must be expected where marginal sediments are being examined. Its recognition would be difficult without the aid of the reef fauna, since dips will be likely almost to coincide with those of the underlying limestone, although the actual junction may well be sharp, somewhat irregular, and represent a nonsequence. A flat-reef may well pass laterally into normal bedded limestones without a reef fauna, and its extent will be difficult to determine away from the margin of the block.

The above cases all deal with types of sedimentation leading to comparatively well bedded limestone, even though the bedding planes of types (*a*) and (*b*) were never horizontal. There is yet another mode of deposition to which the prefix " reef " has been applied.

(*d*) *Unbedded Reef Limestone.*

The chief feature of this type of sediment is its massive character. It is usually possible to make out planes which suggest bedding, but they are far apart, ill-defined, and it takes practice to see them. Well bedded limestone may pass rapidly upwards into this type, and bedding may reappear quite suddenly at the top. It is logical to assume that it passes laterally into bedded limestone in the direction of the massif area of sedimentation. How it behaves on passing towards the basin is a matter for conjecture, since it is usually exposed at a scarp, facing towards the basin.



TEXT-FIG. 3.—Unbedded reef limestone as generally exposed at a scarp face. The difference in resistance and weathering may lead to the formation of knoll topography in such cases.

This type of " reef " is illustrated in Text-fig. 3. Zoning such a limestone is difficult, because of the extreme rarity of fossils. Those that are found are not usually diagnostic of age. The bedded limestones above and below must be relied upon to give the upper and lower limits of age.

Such rocks occur in the Craven marginal belt at Scaleber, Malham, and Cracoe. They have been shown to underly normally bedded limestones of proved age, and to pass laterally into normally bedded fragmental limestones of massif facies. (Anderson, 1929, Hudson, 1930.)

These various modes of accumulation can be classified as follows :—

Reef Facies
- Basinal Reefs — Including reef-knolls, and possibly other types as yet undescribed.
- Marginal Reefs
  - Reef-knolls.
  - Apron-reefs.
  - Flat-reefs.
  - Unbedded reefs.

It is possible that the occurrences which are thought of as basinal at

the moment, such as the C zone reefs of the Clitheroe and Bowland districts may have been more or less marginal at the time of their deposition. The facies may have migrated northwards as the block became progressively submerged. Hudson (in paper read to the Geological Society in January, 1949) has shown that the facies belts did move in this manner in the Malham part of the Craven lowlands. No attempt is made under these circumstances to classify basinal types any further.

(2) Fauna

To those who have worked on these such sediments, "reef fauna" has a clear meaning, but it is not easy to define it. The fauna from the Cracoe Knolls contains goniatites, gastropods, lamellibranchs, brachiopods, corals, trilobites, ostracods, bryozoa, algae, and nautiloids, the association of which gives a familiar appearance to faunal lists. But it is not easy to say of most of the species that they indicate a "reef environment". Even the goniatites appear elsewhere in more normal sediments. The *Beyrichoceras hodderense* band in the Pendle area is a case in point. Perhaps the most characteristic forms are the inflated productids. It is, however, the general assemblage which is so typical. It is this fact which makes age determination difficult. The reef fauna has a similar composition whatever the age of the deposits. The faunal lists from Clitheroe (Parkinson, 1926, 1936) have a generic resemblance to those from Cracoe, though the former are of C age and the latter D. Nevertheless, the age can generally be determined from the occurrence of certain rare individuals of corals and brachiopods which are diagnostic of age in the standard successions. The great abundance of individuals of the reef fauna makes forms of zonal value seem rare in the extreme. The faunal aspect is, therefore, not stressed in the present discussion. After all, the fauna is dependent upon environment, and all the types of sedimentation described above might at times come within the limits of depth, turbulence, and clarity required by those forms which are normally envisaged as the typical reef fauna. There are various types of marginal limestones in the Cracoe Belt, and the faunas vary in abundance and composition in the different members of the succession.

The fauna of apron-reefs might be expected to show the greatest variety since they must indicate a considerable range of depth. At Castleton, for instance, the exposed relief of the erosion slope is of the order of 550 feet. Assuming the cliff line to be near sea-level, a depth zoning of the fauna would be expected, unless most of the forms lived in the shallow water at the top of the slope and fell to the bottom when they died.

Once flat- and apron-reefs were able to form simultaneously such

considerations might offer a reason for different faunal assemblages from deposits of the same age.

Terms describing sediments

Four different ways in which sedimentation occurred have been described above. Within each, limestones of various lithology may be found. These should have a nomenclature describing their lithology not to be confused with the terms used in describing sedimentation.

In the case of unbedded reef limestone the main body of the rock is invariably pale-coloured unfossiliferous calcite mudstone. The other three types lead to the formation of a variety of limestones, for many of which the usual descriptive terms are applicable without the use of the prefix " reef ".

The most conspicuous and best known consists almost entirely of shells or shell fragments. It may be found in apron-reefs, flat-reefs, or reef-knolls. It seems unnecessary to call this anything more than *shelly limestone*. Shelly limestone need not necessarily be confined to marginal areas between basin and massif, but it is common in them. Where it can definitely be related to the margin between the block and basin it could be termed marginal shelly limestone. Under conditions of apron-reef sedimentation, breccia is a common rock type. Such breccias are underwater screes and an appropriate term is *reef breccia*.

Under the peculiar conditions of marginal sedimentation local accidents of deposition must have been frequent, leading to restricted occurrences of peculiar deposits. Local shoaling would produce lenses of peculiar lithology and fauna. There is an example in a quarry on Langerton Hill, near Appletreewick, in the Cracoe district, where a lens of goniatite rock occurs. Such abnormalities could be termed shoal-reef limestones. They could occur among flat-reef sediments, and as local pockets within unbedded reef limestones. Such pockets are sometimes found in the Cracoe section of the Craven marginal belt and also at Scaleber. They account for most of the fossils from these calcite mudstones. It is difficult to imagine such shoal-reefs occurring in sediments with steep original dips, such as true reef-knolls and apron-reefs, although if the shoal produced a considerable local thickening it might be difficult to decide whether it was a shoal-reef or a true reef-knoll in miniature.

Tufa, as noted by Tiddeman (op. cit.) is commonly found among marginal sediments. It must be primary, since it encrusts individual shells and corallites, as well as lying on the bedding planes. Its presence indicates that the surface was subject to temporary drying up, either tidal or of longer duration.

Reef tufa could occur in any of the main types of marginal sediments,

but its presence must imply conditions so shallow that frequent temporary drying up could take place. It is likely to be rare in apron-reef sediments, where it would imply a considerable lowering of sea-level. Although such tufa is common it should not be used to define a type of sedimentation, but as a purely lithological term.

Other types of limestone are found within the marginal belts. Crinoidal and grain limestones occur but they are not confined to or even typical of true marginal facies and they do not need separate descriptive terms. Crinoidal limestone and the presence of chert among the sediments at Cracoe coincided with periods during which marginal facies sediments were not formed. If the differences in stability between block and basin were temporarily eliminated accumulation of normal sediments could take place across the whole area.

(3) Folding, Faulting, and Erosion

Marginal sediments are not immune from such post-depositional changes, yet luckily those of the north of England seem to have escaped severe tectonic disturbance. The chief exception is the Cracoe district, in which folding or faulting have been considerable, and it is a difficult area to interpret in consequence.

By a lucky accident most of the marginal sediments suffered quick burial by muddy seas which deposited soft sediments such as the Edale and Bowland Shales. Their rapid removal re-exposes the topography very much as it was before burial.

(4) Topography

The term knoll is defined in the dictionary as "a small hill, mound", and used in this purely descriptive and topographic sense it has no sinister geological implications. However, once it is combined with the word *reef* it should only have the precise meaning which Tiddeman intended when he first used it.

Applications to Northern England

In the Castleton district of Derbyshire the bedded D_1 limestones occasionally pass laterally into a type approaching unbedded-reef, as the edge of the present scarp is approached. These and the overlying bedded limestones are sharply truncated by the erosion surface, and form the core against which apron-reef material, including breccia, was laid down. Flat-reefs are present on the surface of the plateau on the massif side of the scarp. Various lithologies are represented, including shelly limestone.

The area, therefore, shows a combination of three types of marginal

sedimentation, practically no knoll topography, and no true reef-knolls. There is a minimum of disturbance by later earth movements.

The Craven marginal belt is exposed in three sections, all of which belong to a once continuous belt of marginal reef sediments. These are the Settle-Scaleber, Malham, and Cracoe-Burnsall areas.

In the Scaleber Beck section, which cuts across the strike of the limestones, the exposures begin with well-bedded limestone, and pass rapidly up into unbedded reef limestone which, as usual, is poor in fossils and porcellanous in texture. This is succeeded, apparently without a break, by shelly limestones which may represent flat-reef, and contain a reef fauna. The section continues with upper D_1 limestone of a normally bedded type. Topographically, knolls are very poorly developed in that part of the limestone succession which is of marginal facies. The most knoll-like topographical feature is Sugar Loaf Hill, which is made of bedded shales and limestones of D_2 age.

In the Scaleber area there is nothing which could be called apron-reef, although it may have been removed by pre-Bowland shale erosion.

The central part of the belt, around Malham, shows slightly different features. Here, the hills Wedber and Cawdon show a core of unbedded reef limestone of S_2D_1 age underlain by better-bedded material, with a scarp slope towards the basin on which apron-reef sediments still adhere. There is a suggestion of faulting at right-angles to the scarp which has allowed pre-Namurian erosion to round off the underlying limestone into a subdued Knoll topography. It is better developed than at the same horizon at Scaleber.

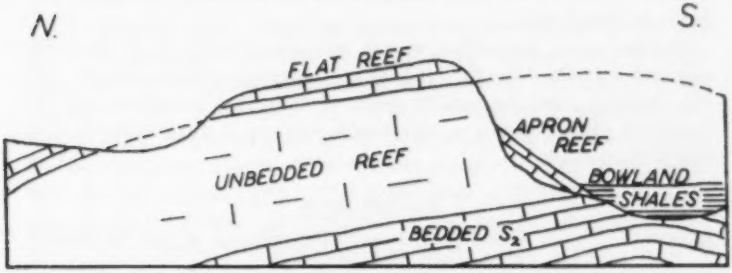
Apart from faulting, there was little tectonic disturbance at Malham, and original dips can be seen on the apron-reef.

The Cracoe-Burnsall section of the belt is the most complex in many ways, as well as the largest area of marginal sediments exposed in the district. Knoll topography is strongly developed, but it is carved from normally bedded limestones as well as marginal sediments. Skelterton Hill has a typical knoll form, but is entirely composed of bedded limestones of basin facies. Carden Hill, though much smaller, is also composed of normal sediments. Across the Wharfe, in the Dibb Valley, Langerton Hill, though including a little shoal-reef limestone, is largely made up of sediments which are of massif facies.

Of the others, Elbolton and Swinden may be taken as typical. Elbolton consists of a core of unbedded reef limestones, with a steep scarp face on the south. These overly normally bedded sediments which can be seen in places round the flanks. The top of the hill slopes gently northwards, and is a dip slope. The topmost beds are shelly limestones of the flat-reef type, but their northerly dip is tectonic, not original. On the scarp face a small patch of apron-reef rests upon the

eroded surface and has yielded P_{1a} goniatites. Its dip is original, not tectonic. A sketch section through Elbolton is given in Text-fig. 4.

Swinden, which has been well exposed by quarrying, shows a core of unbedded reef limestone folded into an anticline pitching north-east. This is covered by the same type of flat-reef sediments with grain and shelly limestones, as the summit of Elbolton. They are folded with the underlying unbedded reef limestone, and the dips are tectonic, not original. The same shelly and grain limestones can be found on the other knolls, Butterhaw, Thorpe Kail, Byra Bank, and Hartlington Kail, in the same relation to the unbedded reef limestone. To make this



TEXT-FIG. 4.—Sketch section through Elbolton in the Craven Reef belt show the deceptive double unconformity in the Southern face. Apron reef deposits of P_{1a} age rest unconformably on D_1 unbedded reef, and E_1 Bowland Shales lie horizontally in the pre-Namurian erosion hollow.

shelly and grain limestone and the tufaceous limestone often found with it into apron-reef instead of a widespread of flat-reef, it is necessary to regard all the dips as original and to postulate a surface below it of extraordinary complexity. On the other hand, if the two are treated as conformably deposited over a wide area and subsequently folded, block faulted and eroded, a reasonable reading of both sedimentation and tectonics is possible. Furthermore, it is difficult to see how the unbedded reef limestone could have accumulated as distinct mounds, since it is practically devoid of recognizable organic material, either microscopic or macroscopic. If the water had been rough enough to reduce the material to so fine a state, it would surely have distributed it far and wide, not built it into restricted mounds. If it is regarded as a once continuous belt of lagoonal sediment it forms a natural extension of the belt of similar rocks, which runs through Malham and Scaleber, parallel with the margin of the massif area of sedimentation, and passing laterally into it away from the margin.

At Cracoe the excellence of the Knoll topography is due to the coincidence of the marginal facies belt with a series of fold axes and

associated cross faults. The fold axes strike obliquely across the facies belts. Pre-Namurian erosion shaped the resulting blocks and, as in other areas, the topography was buried in soft shales. In the remainder of the belt fold axes were absent, and the pre-Namurian erosion was provided with raw material which differed in this important respect.

Application of a scheme of nomenclature such as that described above might help to remove some of the difficulties at present hindering agreement on some aspects of the geology of the Lower Carboniferous rocks of reef facies. Their ultimate explanation must take into account the behaviour of the sub-Carboniferous floor, whose deep-seated movements determined the lines along which sedimentation changed from basin to massif type.

In conclusion, the author wishes to thank Dr. R. G. S. Hudson, who has read the MS., for his helpful suggestions and comments, and Dr. Shirley, who personally demonstrated the intricacies of the Castleton district during a visit which resulted in much friendly and useful discussions.

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An Upper Eocene Outlier at St. Ann's Hill, Chertsey

By H. G. Midgley

Abstract

An outlier of the Bagshot Series occurs at St. Ann's Hill, Chertsey, where beds of the Bagshot, Bracklesham, and Barton sub-divisions are exposed. The division into these beds by pebble bed junctions is suggested. Heavy mineral analyses using percentages of fresh and abraded grains of three indicator minerals, viz. tourmaline, rutile, and zircon, suggests that the divisions postulated are justified.

Introduction

ST. ANN'S HILL shows an almost complete section of the beds formerly known as the " Bagshot Series " as it is found in north-west Surrey. When the section was described by Woodward (1909) it was difficult to recognize all the strata listed by Prestwich (1847), as the section was much disturbed by slipping and so was obscured. In 1940 the demand for sand led to the opening of the pits on the north-east side of St. Ann's Hill. This paper deals with the data obtained from a study of these new openings and of the old sections as now visible. No fossils have been found in these beds, but it is possible to divide them into three groups, with prominent pebble beds as junctions, by a study of the variations of the heavy minerals. It has not yet been possible to correlate these divisions with the Bagshot, Bracklesham, and Barton of the type localities.

The Succession

St. Ann's Hill is an outlier of the " Bagshot Series " surrounded by Thames river gravels. The summit rises to approximately 220 feet O.D., and is about 160 feet above the surrounding country. Although the London Clay is not seen in any of the sections at or near St. Ann's Hill, it is known to be present below.

The succession exposed at St. Ann's Hill can be summarized as follows :—

Pleistocene	1. A thin capping of gravels	0–5 feet
Barton	2. Brown sands with a pebble bed at the base	10 feet
Bracklesham	3. Green and brown sands with clays	60 feet
	4. Glauconitic sand 5. Pebble bed 6. Glauconitic sand	2 ft. 6 in.
Bagshot	7. White and yellow sands	15 feet
	8. Yellow fine-grained sands with two clay bands	6 feet
	9. Green, very fine-grained sands seen to 6 feet.	

Pleistocene

This gravel is probably of Pleistocene age and consists of black flint pebbles. The pebbles are well rounded and average 1½ in. by 1 in. by ½ in. Rolled chert pebbles have been recorded by Irving (1887). These probably came from the Lower Greensand and their presence seems to indicate that the Wealden dome had been denuded as far as the Hythe Beds when these gravels were deposited. This bed compares with the capping found on the surrounding heights, e.g. St. Georges Hill, Oxshott Heath, etc.

Barton

The Barton Beds consist of medium-grained sand (average diameter 0·5 mm.) with a pebble bed at the base. The sand consists of rounded, iron-stained, brown quartz grains, with some rounded white quartz grains and a few grains of glauconite. The pebble bed, about 18 inches thick, consists chiefly of rounded black flint pebbles with a few sub-angular ones. The matrix consists chiefly of a medium-grained brown sand consisting chiefly of rounded, iron-stained quartz grains (average diameter 0·5 mm.), and a fine fraction consisting of angular quartz grains of diameter 0·05 mm. A few angular flint fragments (average diameter 5·0 mm.), rounded flint grains (average diameter 1·0 mm.), angular quartz grains (average diameter 0·25 mm.), sub-angular quartz grains (average diameter 3·0 mm.) also occur. There are also a few grains of glauconite in the matrix, which is probably resorted Bracklesham material. The pebbles of the pebble bed are sometimes cemented together.

Bracklesham

The Bracklesham beds consist of sands and clays with a pebble bed near the base. The sandy beds are composed of medium-grained, reddish sand (average grain size 0·25 mm. to 0·5 mm. diameter), containing a few glauconite grains, a few flint chips, and also numerous clear, glassy quartz grains, which may be as large as 2·0 mm. in diameter. The numerous clay beds may be as thick as 4 inches and weather red. These clay bands are important. One forms the floor of the dingle, which was at one time a pit, but is now a public park near the top of St. Ann's Hill. This clay bed holds up water to form a lake on the pit floor.

The clay beds do not consist entirely of clay material but contain a very small percentage of coarser particles, up to 0·25 mm. in diameter. At the base of the Bracklesham is a pebble bed about 26 inches thick, with a thin glauconitic sand bed above and below. The glauconitic sands contain a very high percentage of glauconite and are dark green in colour. The sand is of medium grain size (0·25 mm. to 0·5 mm.

diameter), with a small amount of fine material (0·1 mm. diameter). There is a little iron staining of some of the fine material. A number of clear, glassy quartz grains occur, some of which are angular.

The pebble bed consists of a partly consolidated conglomerate composed of about equal proportions of rounded pebbles and pebbles which were rounded but have since been split in two. There are also many small fragments of flint which show no sign of rounding. All the pebbles examined were of flint, some being light in colour. The sandy matrix is of medium grain size and light brown in colour. The pebble bed and glauconitic sands appear to be resting in hollows cut into the Bagshot beds below.

Bagshot

The Bagshot beds consist of fine-grained pale coloured sands with very fine-grained green sands at the base. There are occasional clay bands throughout. Two prominent clay bands, about 3 feet apart, occur about 16 feet below the pebble bed at the base of the Bracklesham. The topmost bed, about 15 feet thick, consists of white to pale yellow fine-grained sands with an average grain size of between 0·1 mm. and 0·05 mm. diameter. There are some clear, glassy angular quartz grains and a few iron-stained quartz grains but no glauconite. The sand between the prominent clay bands is a fine-grained white sand (average diameter 0·1 mm.) consisting chiefly of white quartz grains, i.e. not iron-stained. A few of these are clear and glassy. The clay bands are persistent and are composed of a stiff white clay (pipe clay). The lower clay band is thicker than the higher one, and it may be as thick as 4 inches in places. This clay band contains a few ironstone nodules, consisting mostly of ochreous material. A few fragments of a hard ironstone occur, consisting of sand grains cemented by limonite. This occurrence of ironstone in the lower clay band suggests that it was formed by iron-rich solutions held up by the impervious clay band. In the sands a few specimens of lignite were found ; they were rounded, showed little structure, and had apparently suffered some wear before deposition. The basal fine-grained sand, seen to 6 feet, consists of a white fine-grained sand with a high proportion of silt (grain size from 0·1 mm. to 0·05 mm. diameter). The grains are mainly angular, and there are many clear, glassy quartz grains.

Stratigraphy

The " Bagshot Series " of St. Ann's Hill district was divided into Upper, Middle, and Lower by Prestwich (1847). The correlation of the subdivisions with beds found in other areas is difficult owing to the paucity of fossil evidence. Some of the sands of the Middle series of St. Ann's Hill area were shown to be of Bracklesham age by

Monkton (1883). The top pebble bed was classed as Bartonian by Woodward (1909), who wrote: "At St. Ann's Hill . . . an outlier of Bracklesham beds is shown on the map; this is capped by 10 feet or more of flint shingle, forming a pebble bed which is sometimes cemented to form a puddingstone. It rests on the Bracklesham Beds and is now grouped at the base of the Barton Beds."

There was in the past some difficulty in deciding the stratigraphical position of the pebble beds. Woodward (1909) thought that there was only one pebble bed, assuming that the pebble bed found in the pits on the north-east side of St. Ann's Hill—i.e. the pebble bed here placed at the base of the Bracklesham beds—was the upper pebble bed slipped down the hillside. Also it is not clear how much of the beds exposed at St. Ann's Hill, if any, should be classed as Bracklesham. In any case any divisions that may be decided upon petrological evidence alone may not be equivalent to the divisions of Bagshot, Bracklesham, and Barton as defined on fossil evidence.

Petrography of the Beds

In order to ascertain if petrological evidence would throw any light on the stratigraphical problems involved, the heavy minerals of the sands of the Bagshot Series were examined. The following minerals were found to be present: zircon, rutile, tourmaline, kyanite, amphibole, staurolite, anatase, brookite, monazite, epidote, iron-ores, and glauconite. The relative frequency of occurrence of the commoner minerals in certain beds was determined by counting the various grains in a number of microscopic fields, and the results are shown in Table 1.

Table 1.—Percentage of Heavy Minerals in the "Bagshot Series" of St. Ann's Hill

		Zircon.	*Rutile.*	*Tourmaline.*	*Kyanite.*	*Amphibole.*	*Staurolite.*	*Anatase.*	*Iron Ores.*	*No. of Grains counted.*
	Barton sands	32·8	5·7	1·2	1·5	2·6	0·4	0	55·8	751
	Pebble-bed at base of Barton Beds	53·1	5·6	0·9	0·5	0·5	0·1	0	39·0	815
	Bracklesham sands	17·5	5·8	3·1	0·7	0·1	0·1	0	72·7	800
	Glauconitic sand at base of Bracklesham	31·7	8·1	0·9	1·6	0·7	1·3	0	55·7	557
	Pebble-bed at base of Bracklesham Beds.	25·8	9·1	1·0	1·3	2·1	1·3	0	59·4	585
Bagshot.	Yellow sands	35·0	7·1	2·7	1·2	0·4	0	2·5	51·1	752
Bagshot.	Sands and clays	30·5	3·7	0·7	0·7	2·3	0	1·6	48·7	960
Bagshot.	Fine-grained sands	44·5	3·6	2·0	0·7	0·9	1·1	2·2	45·0	573

From these frequencies it can be seen that there is no consistently marked change in the frequency of occurrence of the different minerals from bed to bed on the three series.

Recourse was therefore made to a study of the shape shown by certain grains. It was found that the commonest non-opaque heavy minerals, zircon, rutile, and tourmaline could be divided into two classes :—

(*a*) Fresh, euhedral, and subhedral grains.

(*b*) Abraded and rounded grains.

Each mineral was dealt with separately and counts of the two classes were made. For each mineral the counts made of the two types were expressed as percentages of the total number of grains of that mineral. For simplicity only the percentages of the fresh grains are recorded in the Table 2. As in some cases only a few grains were counted, the total number of grains counted is also given in Table 2.

It can be seen from these results that the Bagshot Beds contain a high percentage of fresh grains of rutile and tourmaline and a low percentage of fresh grains of zircon ; while in the beds above, Bracklesham and Barton, there is a low percentage of fresh grains of rutile and tourmaline and a high percentage of fresh grains of zircon.

The percentages of fresh grains of zircon, rutile, and tourmaline also show sympathetic variation, that is, the minor fluctuations of the frequency of occurrence of the fresh grains all show the same variations

TABLE 2.—PERCENTAGES OF FRESH GRAINS

	Tourmaline		Rutile		Zircon	
	No. of grains counted.	Per cent of fresh grains.	No. of grains counted.	Per cent of fresh grains.	No. of grains counted.	Per cent of fresh grains.
Barton sands . . .	15	14	70	3	89	52
Pebble bed at base of Barton . . .	10	0	100	2	192	34
Bracklesham sands . .	30	13	41	5	118	42
Glauconitic sand at base of Bracklesham . .	10	0	48	0	227	37
Pebble bed at base of Bracklesham . .	11	9	32	15	123	50
Bagshot yellow sands .	15	80	32	78	228	10
Bagshot sands and clays .	38	66	70	64	232	4
Bagshot fine-grained sands	17	64	26	76	134	20

from bed to bed, i.e. when the percentage of fresh grains of zircon increases so do the percentages of the other two minerals.

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New Trilobites from Girvan

By James L. Begg

(PLATE XIV)

Abstract

Five new trilobites from the Girvan district are recorded and described. A new *Proetus* is remarkable for the great width of the anterior shield, the squat glabella, and the great length of the genal spines. Another small proetid is referred to Kegel's subgenus *Cyphoproetus*. The genus *Asaphus* is rare in the Girvan district, and beyond a thorax and an incomplete anterior shield from the Drummuck Group of Lady Burn (Ashgillian) the only record appears to be of three species of *Asaphus* (*Isotelus*) from the Balclatchie Group. Recently three pygidia of *Asaphus*, which may be referrable to Raymond's doubtful genus *Homotelus*, have been found in the *Orthis confinis* beds at Minuntion, Barr Series (Caradoc) The most interesting find is probably a new species of the hitherto monospecific genus *Teratorhynchus*.

Description of Species

Family : **Proetidae** Hawle & Corda, emend. Rud. Richter, 1913

Genus : Proetus Steininger

Proetus fardenensis sp. nov.

Pl. XIV, figs. 1, 2

Description.—The head-shield is semicircular in contour and is more than twice as broad as long. The glabella measures two-thirds the length of the cephalon ; it is subquadrate in form with well-rounded antero-lateral angles, the basal angles being rather less so. It rises abruptly from the cheeks with only a gentle convexity on its surface. No glabellar furrows can be detected. The axial ring, separated from the glabella by a deep nuchal furrow, is broad and bears large lateral lobes. The cheeks and preglabellar area slope down very gently to the lateral and anterior borders. The border surrounding the head-shield has been partly removed, leaving the terraced lines of the under side of the doublure exposed to view. The posterior border of the cheek, which is separated from the cheek by a broad, well defined furrow, meets the lateral border at the genal angle to form a broad genal spine which tapers to a sharp point after reaching the level of the sixth thoracic segment. The palpebral lobes are semiannular in form, very large. The anterior branches of the facial sutures curve forwards and outwards to cut the anterior border a great distance apart. The posterior branches are short, directed backwards and outwards, cutting the posterior cheek border at an oblique angle. The thorax is partially enrolled, leaving some six segments visible which appear to be of the

normal proetid type ; the axis is broad, anteriorly about one-third the width of the thorax ; each thoracic ring bears large lateral lobes which are only slightly less in size than the lobes of the nuchal ring ; the pleurae are deeply furrowed, pointed at the outer ends and bent gently backward. The pygidium is unknown.

Material.—One example only, the holotype B.G. 11894.

Dimensions.—

	mm.
Length of cephalon	5·5
Width of head-shield at genal angles . .	13.0
Length of genal spine	4·5

Horizon and Locality.—Drummuck Group (Ashgillian), Upper Starfish Bed, Lady Burn, Girvan.

Remarks.—The present example differs greatly from the normal proetid of Ordovician age, as seen in such forms as *Proetus girvanensis* Nicholson & Etheridge (1879, p. 169, pl. xii, figs. 7, 8, 9) *P. chamblienensis* Foerste (1914, p. 320, pl. 4, figs. 1 A–H), and *P. groenlandicus* Troedsson (1929, p. 53, pl. 16, fig. 1). It is distinguished from these forms by the unusual width of the head-shield, the form of the short broad glabella, the presence of a preglabellar area, and the extraordinary size of the eye lobes, which in length almost equal the glabella. The long genal spine is another feature which distinguishes this example from other proetids of Ordovician age, but is not uncommon in species of Lower and Middle Devonian (such as *Proetus* (*Decorproetus*) *concentricus* Pribyl and *P.* (*Xiphogonium*)—(Barrande)).

It may be compared, however, with *P. scobiei* Begg, from the same locality and horizon ; there is a close similarity in the semicircular contour of the head-shield and in the wide form, but *scobiei* possesses a bell-shaped glabella reaching forward to the anterior furrow and it has glabellar furrows ; the eyes in *scobiei* are much smaller and placed farther forward. The genal spine is much shorter. Since the above description was written I have seen Dr. A. Lamont's description and figure of *Proetidella fearnsidesi* n.g. et n. sp. (1949, p. 304, pl. 10, fig. 23) from Horderley, which has many features in common with this Ashgillian trilobite. The semicircular contour of the head-shield, along with its extraordinary width, the short subquadrate glabella, the large palpebral lobes, the deep nuchal genal furrow, and the course of both anterior and posterial facial sutures. All compare closely in the two trilobites. In the Girvan example, however, the glabella does not reach the anterior furrow and it possesses a genal spine which is both broader and longer than the Horderley example.

I am uncertain that this Girvan example should be considered congeneric with Dr. A. Lamont's proposed genus *Proetidella*, and accordingly simply name it *Proetus fardenensis*.

Proetus subtriangularis sp. nov.

Pl. XIV, fig. 6

The glabella is subtriangular in outline, well rounded anteriorly, and at basal angles, strongly convex transversely ; longitudinally it rises rather abruptly from a flat, narrow platform in front of the glabella, then curves back to the posterior end with a very gentle convexity ; glabellar furrows are lacking. The nuchal ring is broadest medianly, where it is equal in width to the nuchal furrow ; both ring and furrow are on a rather lower level than the glabella. A narrow platform surrounds the glabella anteriorly and at the anterior portion of its sides ; anterior to this platform a gently concave preglabellar field extends to the narrow rim. The anterior branches of the facial sutures cut the anterior border not far apart.

Material.—One example only, the holotype B.G. 11896.

Dimensions.—

	mm.
Length of glabella	4·0
Basal width of glabella	3·0
Total length, anterior to glabella	2·0
Width of nuchal furrow and ring	1·0

Horizon and locality.—(Mid Valentian), Saugh Hill Group, Newlands, near Girvan.

Remarks.—This example, in its general aspect, closely resembles *Clypoproetus asteroideus* Begg, an Ashgillan proetid from the Drummuck Group, but differs in two material features ; the Drummuck proetid has two discrete basal lobes and the anterior branches of its facial sutures cut the antero-lateral angles far apart.

Subgenus : CYPHOPROETUS Kegel, 1927

Cyphoproetus newlandensis sp. nov.

Pl. XIV, fig. 7

The glabella is ovoid, moderately convex, and constricted at base ; the basal lobes are detached, subtriangular, rounded at the base, and pointed anteriorly ; the nuchal ring is moderately broad and bears a median tubercle. The large preglabellar field curves down to the flat anterior band in conformity with the anterior slope of the glabella.

Material.—One example only, the holotype B.G. 11895.

Dimensions.—

		mm.
Total length	*circa*	4·75
Anterior width	,,	3·0
Length of glabella	,,	2·5

Horizon and locality.—Saugh Hill Group (Mid Valentian), Newlands, near Girvan.

Remarks.—The subgenus *Cyphoproetus* was founded by Kegel

(1927, p. 636, pl. 32, fig. 11) on *Cyphaspis depressus* Barrande. The form of the glabella and the discrete basal lobes are features which recall *Otarion* Zenker (= *Cyphaspis*), the thorax and pygidium being more closely related to *Proetus*, and the subgenus is considered to be a transitional stage between *Otarion* Zenker and *Proetus* Steininger. Pribyl (1945, p. 16) classifies it with *Proetus* and places it in the subfamily *Proetinae*. While there is, no doubt, great difficulty in ascertaining its closest proetid affinities this correlation appears questionable, since it differs very considerably from all genera in the *Proetus* (*Proetus*) group. Pribyl states that it can be " immediately distinguished from all other proetid genera and subgenera by its simple (basal lateral) pair of deep-cut glabellar furrows dividing the basal lobes, further by the general shape of the cephalon and pygidium ". With regard to the discrete basal lobes, this writer appears to have overlooked that this feature distinguishes Reed's genus *Warburgella*, and the pygidium seems to be at least as closely related to *Proetus* as to *Otarion*.

As concerns the present small cranidium, it differs from the genotype in two features—the basal lobes are rather narrower, and although the anterior band closely resembles that of Kegel's subgenus, the preglabellar field is distinctly different. In *Cyphoproetus depressus* there is a definite but a very narrow preglabellar field, while in the present example this area is comparatively broad and curves down to the anterior band.

Of the four species of *Cyphoproetus* known this example from Newlands resembles most closely *C. rugosus* Bouček in the small size of the former and in the form of the glabella and its basal lobes ; but it differs in the anterior band, which in Bouček's species is broad and rises up abruptly.

Family **Asaphidae** Emmreich

Genus HOMOTELUS Raymond

Homotelus stincharensis sp. nov.

Pl. XIV, figs. 4, 5

A defective pygidium, semicircular in outline, broader than long, and possessing a feebly defined concave border most strongly developed posteriorly. The axis is moderately broad anteriorly, but tapers between curved axial furrows to become very narrow posteriorly, and it measures about four-fifths the length of the pygidium. It is much better defined at its posterior end than at other parts. A paratype has the same semicircular form, broader than long, with well rounded anterolateral angles. The greater part of this pygidium is decorticated and the axis not preserved, but its anterior width can be estimated by the two notches on the anterior border ; it measures about one-third of the

anterior width of the pygidium. Part of the doublure is exposed, showing the inner side bending steeply down and the outer part rather flat ; some terraced lines are visible.

Material.—Two pygidia, holotype, no. 88880, paratype, 88881.

Dimensions.—

		mm.
Holotype,	length of pygidium . .	19
	width „ „ (*circa*) .	26
Paratype,	length of pygidium . .	25
	width „ „ . .	40

Horizon and locality.—Orthis confinis beds, Barr Series (Ordovician), Minuntion, by Pinmore, Girvan.

Remarks.—In erecting the subgenus *Onchometopus* for his species *volborthi*, Schmidt placed special emphasis upon the hooked character of the doublure of the front of the glabella. It was used as a generic name by Raymond (1910, 7, no. 1, pp. 51 and 63) in describing a new species of trilobite from the Middle Ordovician of Minnesota and Pennsylvania. The essential features of the form for which the name has been used are the isoteliform glabella and sutures, but asaphiform lack of concave borders on the shields. The same author (1925, p. 87) states that *Onchometopus* is a derivative of *Asaphus*, while *Homotelus* sprang from *Isotelus* ; and that while *Homotelus* lacks concave borders on the shield " often specimens are found in which concave borders are feebly or sometimes well developed ". He considered further that *Homotelus* cannot be regarded in a strict sense as a good genus, but it is a convenient term for a number of species showing similar characteristics. Wilson (1947, p. 21) states that *Homotelus* differs from *Isotelus* in having more rounded extremities, in lacking concave borders, and having a narrower axial lobe. Determination is rendered difficult when only pygidia are present. The figured pygidia of *Homotelus* given by Raymond (1925, pl. iv, figs. 3, 5 ; pl. v, fig. 7 ; pl. vi, fig. 3 ; and pl. ix, fig. 3) show very considerable variation. The present examples closely resemble *Hometelus laevis*, which is the last of the figures cited above. The only difference appears to be that *laevis* has a broader pygidium. I have compared these examples from Minuntion with pygidia of *Onchometopus* and found the axial lobe of the pygidium of the latter genus to be much broader than that of *Hometelus*. I refer these pygidia tentatively to the genus *Hometelus*, under the specific name *Stincharensis*.

I am indebted to Professor W. F. Whittard for kindly lending me the pygidium which is the holotype of this trilobite. It was collected by the Field Class of the Geological Department of the Bristol University in 1949. Unfortunately, both specimens are poorly preserved, but will be placed in the custody of Dr. C. J. Stubblefield, in the Geological Survey Museum, London.

Family **Remopleuridae** Corda

Genus TERATORHYNCHUS Raymond

Teratorhynchus sp.

Pl. XIV, fig. 3

Near the posterior end the glabella is transversely elliptical, broad, rather flat, and embraced by the large semiannular eyes. The anterior portion is bell-shaped in outline, semicylindrical, much narrower than the posterior portion, and furnished with a short straight anterior spine which is circular in section. There are no glabellar furrows, but a pair of short oblique depressions are present on each side of the posterior portion of the glabella. The palpebral lobes are broad and flat ; the occipital ring is moderately broad and bears a median tubercle.

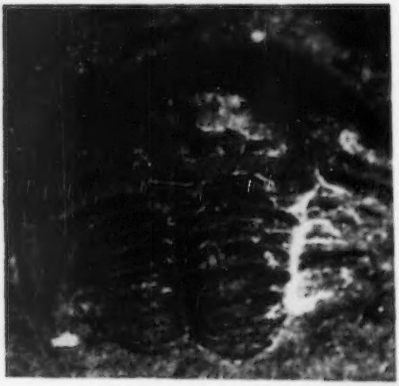
Material.—One example only, holotype B.G. 229.

Dimensions.—

	mm.
Length of glabella	4·5
Posterior width of glabella	5·0
Anterior width of glabella	3·0
Length of spine	1·5

Horizon and locality.—Balclatchie Group (Ordovician), Dow Hill, Girvan.

Remarks.—Reed (1903, p. 33, pl. v, figs. 5–16) described and figured what he termed "a remarkable and bizarre" trilobite, which on account of a general resemblance in essential features was referred to *Remopleurides*. It was considered, however, to be sufficiently distinct to merit subgeneric rank and named *Remopleurides* (*Teratorhynchus*) *bicornis*. The extraordinary development of the two preglabellar spines suggested the subgeneric name. Raymond (1925, p. 56) proposed raising Reed's subgenus to full generic rank, and this was accepted by Reed (1929, p. 8). Hitherto only one species has been placed in the genus, the holotype, but the examples known show a wide degree of variation. In nine specimens of *T. bicornis* I have found the following variations in the length of the anterior portion of the glabella : three measure three times, one one-and-a-half times, and five twice the length of the posterior portion. The specimen described here shows certain features indicating a still greater degree of variation from the holotype of *T. bicornis* than occurs in those specimens just mentioned. In particular the anterior portion of the glabella is proportionately very much shorter, and there is only one preglabellar spine, short and circular in section, whereas in *T. bicornis* there are two which are very long and oval in section. It appears, therefore, that the present example represents a distinct species, but until more complete material is available it does not appear justifiable to give it a name.



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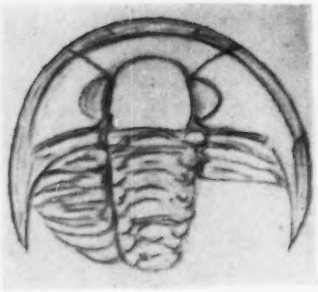

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J. L. B. del. D.B.S. photo.

GIRVAN TRILOBITES.

On the same slab there are a few poorly preserved thoracic segments of the species described. I am indebted to Dr. A. E. Trueman for the suggestion that, meantime, this example should not be given a specific determination. For this and many other kindnesses and help I offer him my grateful thanks.

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EXPLANATION OF PLATE

(The originals of Figs. 1, 3, 6, 7, are in the Begg collection, 4 and 5 in the Geological Survey Museum, London.)

FIG. 1.—*Proetus fardenensis* sp. nov., holotype B.G. 11894 × 4. Head-shield and part of thorax, showing a number of segments ; the pleurae on the side, glabella, and eyes are defective. Upper Starfish Bed, Lady Burn, Girvan.

FIG. 2.—The same, a rough drawing to show the course of the facial sutures which are not distinctly seen on the photograph.

FIG. 3.—*Teratorhynchus sp.*, holotype B.G. 229, × 5½. A cephalon with anterior spine and a few badly preserved thoracic segments. Balclatchie Group, Dow Hill, Girvan.

FIG. 4.—? *Homotelus stincharensis* sp. nov., holotype No. 88880, × 1. A defective pygidium which shows the axis and the concave border. Barr Series, Minuntion, near Girvan.

FIG. 5.—The same, paratype No. 88881, × 1. A pygidium showing part of the doublure and on it some terraced lines. Same horizon and locality.

FIG. 6.—*Proetus subtriangularis* sp. nov., holotype, No. B.G. 11896, × 4. Saugh Hill Group, Newlands, near Girvan.

FIG. 7.—*Cyphoproetus newlandensis* sp. nov., holotype, No. B.G. 11895, × 6 Saugh Hill Group, Newlands, near Girvan.

Darwin and the forgotten Mr. Lonsdale

By Paul Tasch
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Abstract

William Lonsdale's associations with Sedgwick, Murchison, and Darwin are noted and his inference that the " transition series " was Devonian age, derived in 1837 from a study of fossil corals, is interpreted as an unique contribution to the belief that " species undergo modification ". As the first applied evolutionist, it is argued that he belongs on the list of important early contributors to the theory of evolution.

BEFORE publication of the first edition of *Origin of the Species* in 1859, Darwin traced the progress of opinion on the subject in a brief historical sketch. Some thirty-four authors were cited including geologists and palaeontologists. These were the " few naturalists " who " in contradistinction to the great majority . . . have believed that species undergo modification and that existing forms of life are descendants by true generation of pre-existing forms ". One omission which seems curious in view of Darwin's painstaking efforts to acknowledge each and every significant contributor was the name of William Lonsdale. It was not the first time that Darwin had " forgotten to mention " him [1] (C. Darwin, 1844 ; 1859, chaps. x, xi ; 1888, vol. i).

William Lonsdale was born in 1794, commissioned at the age of sixteen, and served in the Peninsular wars. Thereafter he retired to Bath on half pay. For thirteen years (1829–1842) he served as Assistant Secretary and Curator of the Geological Society. Few intimate glimpses of him are available. Murchison recollected having quite by accident come upon him in several quarries, and remembered him as " a tall grave man with a huge hammer on his shoulder ".

Most of Lonsdale's time was spent studying fossil corals in the vicinity of Bath. He amassed an astonishing amount of information, for, after their chance meeting, Murchison was so impressed that he " stayed some days at Bath " under his guidance (Murchison, 1839, chap. ii). Thus began a most fruitful collaboration and friendship. In later years when Murchison was harassed by " friend Sedgwick's tirades " he " conferred with Lonsdale as a confidential friend who was privy to all my progress *in re Siluriana* " (Geikie, 1875, vol. i, letter dated 1846).

We may digress at this point to bring Darwin into the picture. During August, 1831, Darwin, aged 22, accompanied Professor Sedgwick

[1] C. Darwin, 1888, vol. i. Letter to Henslow, October, 1836. " I have forgotten to mention Mr. Lonsdale," Darwin wrote shortly after his return home from the *Beagle* voyage, " who gave me a most cordial reception and with whom I had much most interesting conversation."

on a geological survey of North Wales. About this trip Sedgwick wrote to Murchison : " I was stopped by the fossils over and over again . . . and I had two journeys to London and . . . Lonsdale had come to Cambridge about them " (Clark and Hughes, 1890, letter dated 13th September, 1831). Sedgwick called on the authority of Lonsdale to decipher his fossil corals. Doubtless, this was Darwin's earliest direct acquaintance with Lonsdale's work. October of that same year Darwin embarked on the *Beagle* voyage.

A letter home, written in July, 1834, when one hundred miles south of Valparaiso, informed Caroline Darwin that " among animals, on principle I have lately determined to work chiefly among the Zoophites or Corals " (Barlow, 1946). And, writing from Port Lewis, Darwin informed the same correspondent that " the subject of coral formations has for the last half year been of particular interest to me " (Barlow, 1946, letter dated 29th April, 1836).

One of Darwin's last impressions before leaving on the *Beagle* voyage was the puzzle presented by Sedgwick's fossil corals. One may in part attribute to the curiosity so aroused, his resolution, some three years later, " to work chiefly among the Zoophites or Corals." What part Lonsdale may have had in stimulating this interest is not known, although it is reasonably certain that Darwin must have known of Sedgwick's appeal to him for assistance.

After Murchison and Sedgwick had named the Silurian System, an unassignable " transitional " series remained (von Zittel, 1901, p. 434) ; unassignable, that is, until William Lonsdale gave the correct age. We may briefly trace the steps leading to this achievement by paraphrasing Murchison's recapitulation of events (Murchison, 1854, p. 237).

(1) Establishing the Silurian System as distinct from the Carboniferous.

(2) Sedgwick and Murchison prove the " culm measures " of Devon were Carboniferous.

(3) The Killas graywacke recognized to be of Devonian age and equivalent of the Old Red Sandstone in other regions (Scotland).

Now step number three was not easily or readily reached even though in Murchison's terse language, " it became manifest." In the same discussion he amplifies this somewhat :—

> The highly important deduction, however, of Mr. Lonsdale that the fossils of the South Devon limestone (i.e. coralline faunas) really exhibited a character intermediate between those of the Silurian and of the Carbonaceous limestone was the most cogent reason which induced Professor Sedgwick and myself to propose the term Devonian.

The " zoological evidence " behind Lonsdale's " highly important deduction " is summarized in vol. iii of the *Proceedings of the Geological Society* (Lonsdale, 1840). Of sixty-three species, twelve were common to Carboniferous and Devonian limestone ; forty-two were Devonian only ; and of the remaining nine seven were corals belonging to the Devonian and Silurian.

Despite this evidence the assignment of an age intermediate (Darwin, 1859, chap. ix) [1] between Silurian and Carboniferous to the Eifel corals, was not " immediately " acceptable to Sedgwick and Murchison (Geikie, 1875, vol. i, p. 256) for two principal reasons. Firstly, Lonsdale's inference implied " mutability of species " which they vigorously opposed,[2] and secondly, it was only by a most gradual process that they came to realize that " mineral character " was " no longer indicative of age, and the term graywacke (was) applicable to beds of every class of rocks " (Sedgwick and Murchison, 1839, p. 123). Having painfully attained this realization, Murchison did not hesitate to acknowledge " the superiority of organic remains to mineral characters in identifying the age of rocks " (Murchison, 1839, p. 108).

During the winter of 1838–9 the dubious two " sought anxiously for light from further fossil evidence " (Geikie, 1875, vol. i, p. 264). Box after box of Devonshire fossils were sent to Sowerby (mollusca) and Lonsdale (corals). The tenacity with which they clung to earlier notions may be seen in Sedgwick's letter of March, 1839 : " The Devon fossils are a great puzzle, but I am as firm as ever—no Old Red in Devon."

Two years after Lonsdale deduced the age of the Devon corals, Sedgwick and Murchison in the Spring of 1839 accepted it. Of course, as early as 1837, they had reluctantly gone on record to that effect, but their hearts were not in it, as may be gleaned from Sedgwick's last ditch stand in 1839, " no Old Red in Devon."

A letter to Sedgwick throws light on the magnitude of Lonsdale's contribution, and also discloses the still palpitating annoyance Murchison felt :—

> Buckland summed up at half-past eleven . . . he ended by approving highly of " Devonian "—he now saw the light—that light referred to W. Lonsdale and henceforth, said he, there will be two

[1] " Subject to these allowances, the fauna of each geological period undoubtedly is of intermediate character between the preceding and succeeding faunas. I need only give one instance, namely the manner in which the fossils of the Devonian system, when this system was first discovered, were at once recognized by palaeontologists as intermediate in character between those of the overlying Carboniferous and underlying Silurian."

[2] Darwin refers to Sedgwick and Murchison as among those " who have . . . often vehemently maintained the immutability of species ". (Darwin, 1859, chap. ix.)

great names in English geology—W. Smith and W. Lonsdale ; he adhered entirely to the fossil evidence, did not give us the credit we deserved for our coal trough (which is the key to the whole thing), nor did he do justice to my Siluriana without which, as you have justly said, none could have started this new hare (Geikie, 1875, vol. i, 265–8, dated 11th April, 1839).

Thus as early as 1837 Lonsdale was acknowledged to have pushed to solution a baffling major problem in stratigraphy solely on fossil corals. More significant, however, is that in so doing, he employed for the first time the very evolutionary concepts Darwin was to champion, namely that " species undergo modification " (*vertically*, Lonsdale showed, as applied to rock strata), and that " the existing forms of life are descendants by true generation of pre-existing forms ". Thus the theory of evolution was used as a working tool to determine the age of the " transition " beds by study of modification of fossilized coralline species in the very year (1837) that Darwin noted in his pocketbook, " In July opened first notebooks on Transmutation of the Species."

Murchison affords a glimpse of Lonsdale at work studying modification of coralline species. " His energy," Murchison declared, " astonishes me."

> He assured me that it had cost him three weeks to convince himself that the *Stromatapora polymorpha* was a true species. He admits no species which will not bear the test of explaining in its different parts the production of each, the differences between young and old polyps in their cells, thickness of walls, etc. (Geikie, 1875, vol. i, dated 1846).

Lonsdale himself,

> . . . in advocating the value of fossils (advised) the observer not to depend on his own limited sources of knowledge, but to seek the aid of the philosophical zoologist, who can teach him to reason justly on the distribution of animal life . . . the changes which such accidents may produce, or the means provided by nature to resist them (i.e. the changes or modifications of species)—and on the effects which a permanent alteration in the inhabiting medium may work in form and size of a shell or coral (Lonsdale, 1840, p. 284).

Now, in alluding to " the aid of the philosophical zoologist " for improvement of the palaeontologist's limited knowledge of modification of species, Lonsdale may have had Darwin in mind. We recall that four years before, in 1836, upon Darwin's return from the *Beagle* voyage, the two had had " much most interesting conversation ".

By this allusion several things become clear. There were admittedly

larger problems arising from the modification of species observed in fossil faunas. What, for example, was the mechanism promoting or resisting such change ? How were such changes affected by " alteration in the inhabiting medium " ? These questions, Lonsdale said, were beyond the scope of the palaeontologist. That such changes did occur and were visible to the student of fossil faunas he had no doubt and his own work beautifully demonstrated how to use the observed changes.

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Basement Carboniferous in Upper Teesdale, N. Yorks.

By W. T. Harry

Abstract

Excavations in Upper Teesdale, N. Yorks, exposed basement Carboniferous at its unconformable contact with underlying shales of probable Silurian age. The lowest basement beds are tough conglomerates cut by compression joints. The constituent pebbles are unsorted, locally derived, and mainly andesites and rhyolites, with vein quartz and shale pebbles. A dreikanter outline is common. The conglomerate is contrasted with others also between the Carboniferous and Lower Palaeozoic in England.

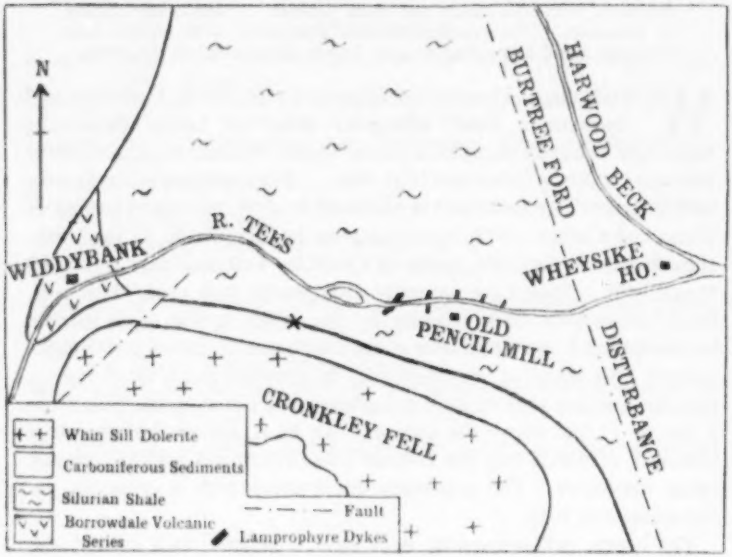
WITHIN the Carboniferous fell country of North Yorkshire and Durham, a small triangular inlier of Lower Palaeozoic shales and volcanics occupies a part of Upper Teesdale roughly midway between Cauldron Snout and High Force. The overlying unconformity and basement Carboniferous is obscured by drift, but was recorded by Gunn and Clough (1878) in excavations they had made on the Yorkshire banks of the Tees, north of Cronkley Fell and near a disused Pencil Mill. These have naturally disappeared with time. However, fresh excavations made recently by the writer in the same locality have exposed 5 feet of basement Carboniferous at its unconformable contact with shales of the inlier and, by cleaning out a small burn a few yards to the west of that, a further 6 feet covering the beds from 5 feet to 11 feet above the contact. An 11 ft. section was therefore obtained, of which only the bottom 3 feet contained pebbles, the rest being sandstone. The exposures are marked with a cross on the accompanying map.

The lower, pebble-bearing, beds have a general dark colour, the phenoclasts being coated by a blue-black lustrous oxide probably deposited by downward percolating solutions trapped and concentrated at the unconformity. The beds are tough and compact, individual pebbles not being easy to extract. Vertical joints, about one foot apart, cut the conglomerate in two sets at right angles, one trending 5° S. of E. Joints with the same trend may be seen in the Carboniferous Limestone and Whin Sill on top of Cronkley Fell. Those in the basement Carboniferous are perfectly plane, closed, often slickensided, and cleave indifferently through pebble and matrix alike. They are considered compression joints, tension joints being expected to avoid the tough igneous pebbles. The pebbles are sporadically distributed in a matrix of highly re-entrant and corroded quartz grains, frequently compound, strained, and with numerous inclusions. The cement is argillaceous or brownish chloritic material. The larger phenoclasts may present a dreikanter outline, such being presumably derived from a previous sub-aerial accumulation formed during the

preceding land period. The rock as a whole is unsorted. A count of 193 pebbles measuring 1½ inches or more in length, gave the following results :—

	Per cent.
Rhyolites and Andesites .	56
Shale	11
Vein Quartz . . .	33

These materials may be matched with rocks in the inlier, which is made



TEXT-FIG. 1.—Map of basal Carboniferous locality, Teesdale, with site of excavation marked by cross, ×. Scale 2¼ in. to 1 mile.

up of similar shales with vein quartz showing strain effects and numerous inclusions, and presumed Borrowdale Volcanics, outcropping in the western corner of the inlier opposite Widdybank Farm on the southern bank of the river.

Quantitatively, however, the inlier is chiefly composed of shales, whereas volcanics predominate in the conglomerate most likely because of their superior resistance to abrasion. Both the composition and shape of the conglomerate constituents argue a local derivation with little transport. Lack of sorting and absence of Carboniferous pebbles further suggests a reasonably rapid and steady subsidence of the Lower Palaeozoic floor during these first stages of the Carboniferous transgression in the district.

The overlying sandstones are poorly graded. A thin section from

5 feet above the unconformity showed a close-knit welded quartz mosaic with little cement. Treatment with HCl produced no reaction, remarkable in a Carboniferous sand. Heavy mineral analyses were marked by an overwhelming preponderance of the more stable minerals, zircon, magnetite, and rutile, the last subordinate to the first in abundance. Derivation from pre-existing sediments is implied. Numerous well rounded zircons, bearing evidence of more than one cycle of erosion, support this view. The lack of garnets, since Borrowdales in the Lower Palaeozoic platform would have supplied a sufficiency, is attributed to mechanical action.

Several different conglomerates occur between the Carboniferous and Lower Palaeozoic in North England, some referred to the Old Red Sandstone, others to the Carboniferous. Doubt may therefore be cast upon the age of the Teesdale occurrence, since its relations with the Carboniferous on top of Cronkley Fell are obscured by boulder-clay. Both agree in dip, however, and comparison with the probable Old Red conglomerates reveals marked differences. Such are commonly red in colour, and include the polygenetic conglomerate of Roman Fell near Appleby whose constituents are far-travelled and deficient in vein quartz. A similar rock occurs at Melmerby, mainly composed of granite pebbles. The Mell Fell beds of the Eastern Lake District measure hundreds of feet thick, and may be torrential deposits accumulated at the foot of a hill range. The Teesdale conglomerate bears little resemblance to all these, and is referred to the basement Carboniferous. An S_2 age for the Carboniferous transgression in the area is indicated by Mr. J. S. Turner's map (1927). Comparison with other basal Carboniferous conglomerates in North England shows the Teesdale beds to be tougher, harder, and more compact, though compression joints do also cut the pebbles in the basal conglomerates of the Austwick district just below Norber Brow. Since this district, like Teesdale, lies well within the Rigid Block some connection may be suggested between the tectonic behaviour of the block and the structure of the lowest beds in its sedimentary skin.

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CORRESPONDENCE

CEPHALIC SEGMENTATION AND SUTURES IN TRILOBITES

SIR,—While one agrees in principle with Dr. Stubblefield's caution (1950), several considerations exist to justify further investigation on the hypothesis that the pseudofrontal lobe of the glabella in trilobites may be trisegmental in origin (Lamont, 1949).

Most authors unquestioningly follow Bernard in saying the trilobite compound eye represents the first segment of the annelid ancestor, but sensory tubercles arranged along raised lines, or sutures, behind those of the compound eyes in *Scotoharpes domina* (Lamont) and *Platyharpes flanaganni* (Portlock) var. ?, indicate that several segments of the ancestor must have had eyes. Consideration of *Dionide*—and probably of *Protolloydolithus* (Williams, 1948)—points to the three transverse lines on each cheek as arising from the pseudo frontal lobe and indicating its trisegmental nature. Again, the compound basal glabellar lobes in *Dionide* are quite like those in *Lioharpes*. From homology between *Dionide* and Harpedidae, it is therefore easy to argue that the three transverse lines in *Dionide* added to the posterior pair that have recently been observed in *Platyharpes*, etc., provide evidence that the forerunner, at least of this group of trilobites, had five pairs of dorsal eyes on a pattern corresponding with that found in the modern leech (*Hirudo medicinalis*). Among other things this new theory allows Ruedemann's much criticized observations (1916, pl. 35, figs. 6 and 7) to be rationally interpreted. In his figures of *Cryptolithus tesselatus* Green, longitudinal sutures seem to pre-date lateral spreading of the glabella, and three pairs of transverse sutures, or eyelines, are present.

My observations of trisegmentation of the pseudofrontal lobe in adult males and females of *Platycalymene duplicata* (Murchison) have been queried by Dr. Stubblefield. The structures I photographed (1949, pl. xviii, figs. 3 and 4) still look like appendifers to me, and I don't see why they should have been preserved in a thin-shelled trilobite if they were not functional. In any case, there is apparent trisegmentation of a similar aspect in what may be taken as young adult males of *Ogygiocaris buchii* (Brongniart) (Salter, 1865, pl. xiv, fig. 4)—cf. superior development of anterior appendages in males of crabs like *Gonoplax angulatus* (Cunningham, 1900, fig. 28). Lack of correspondence between number of appendages and number of dorsal segments in embryos of *Limulus polyphemus* (Woodward, 1866–1878, pl. xxxiii, figs. 2 and 4) may furnish a warning about reliance on the unsegmented or occasional bisegmental appearance of the pseudofrontal lobe in protaspid or meraspid trilobites.

The trisegmental "basal" glabellar lobes in *Phillipsia colei* McCoy, an Irish trilobite occurring late in the stratigraphical column but probably indicating the ancestral condition of many Proetidae and Otarionidae, have been clearly figured by Woodward (1883, pl. ii). In this form the middle part of the facial suture appears to homologize with the longitudinal suture in Harpedidae, lying close to the glabella and its "basal" lobes. While trisegmentation of "basal" lobes in Harpedidae is less clear, the raised lines running out from them on to the alae in primitive and less well calcified species, seems to point to a like interpretation. This may involve the idea that the compound eyes in Proetidae are not homologous with the anterior compound eyes in Harpedidae. Such a conclusion seems very likely if we consider *Brachymetopus strzeleckii* McCoy, in which, in addition to the posterior compound eyes, there are strong anterior tubercles in a position roughly corresponding with the anterior compound eyes of Harpedidae (Cowper Reed, 1903, p. 194, fig. 1).

In the Agnostidae, marked like the Illaenidae by reduction or suppression of maxillipedal and masticatory appendages, it is possible that the "basal" lobes may have been trisegmental. While the posterior part of the glabella is much reduced in length, it is interesting that the anterior often retains

three transverse furrows. Muscle-scars in the agnostid *Phalacroma glandiforme* (Angelin) (Westergård, 1946, pl. 16, fig. 1) show fusion much like that in "*Illaenus*" *proles* var. *shelvensis* Whittard (Lamont, 1939, fig.), and adaptiveness makes it very difficult to trace ancestral segmentation in such families.

Most trilobites show reduction in the number either of the anterior three segments of the glabella or of the posterior three segments. This is the source of the view that there are five segments in the glabella, but the theory that there were originally six segments plus the occipital ring makes for much more intelligible homologies with Arachnida on the one hand and with Vermes on the other. A new interpretation of the trilobite hypostome in terms of prostomium and peristomium of certain worms may also be possible. On the hypostome of *Dalmanites caudatus* (Brunnich) (Salter, 1849, dec. ii, pl. i, fig. 3) and on that of a new late Caradoc species of *Chasmops*, not only are there the well known paired maculae, but near the posterior border occur three pits possibly for small appendages. The maculae may be thought of as comparable with the ciliated pits of the peristomium in *Polygordius neapolitanus*, while the other three pits may indicate the odd number of tentacles seen on the prostomium of marine worms. While naturally no one modern worm can be found to represent an ancestral form for all trilobites, the homologies of the trilobite cephalon now proposed may help to dispose of a theory like that by Ivanov concerning a polyphyletic origin for the trilobites.

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PLATYHARPES WHITTINGTON, 1950, A SYNONYM OF *HIBBERTIA* JONES AND WOODWARD, 1898

SIR,—In my recent (1950) monograph of the British Trilobites of the family Harpidae I erected a new genus, *Platyharpes*, the genotype being *Harpes flanaganni* Portlock, 1843. In 1898 (pl. xxv, figs. 8a, 8b) Jones and Woodward published pictures of a supposed new crustacean genus and species, *Hibbertia orbicularis*, believed to be from the Lower Carboniferous of Scotland. The description was published in the following year (Jones and Woodward, 1899a, 390–393, pl. xv, fig. 4; 1899, 205–8). Withers (1929) recognized that the specimen upon which *Hibbertia orbicularis* was founded was not a crustacean, but should be referred to the Middle Ordovician trilobite *Harpes flanaganni* Portlock, and that it probably came from the type locality in Northern Ireland and not from Scotland. I have examined the specimen and expressed agreement with Withers' conclusions (Whittington, 1950, p. 36). Withers also stated that *Hibbertia* should become a synonym of *Harpes* Goldfuss, 1839. When I selected *Harpes flanaganni* as the type of a new genus I should not have made the new name *Platyharpes* but revived *Hibbertia*, since the genotype is the same. In stating that *Platyharpes* is a synonym of *Hibbertia* it should be pointed out that this synonomy is subjective, since the specimen upon which Jones and Woodward founded their genus is not the diplotype, i.e. the lectotype of *Hibbertia flanaganni* (Portlock, 1843).

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CHALK ROCK OF DORSET—MORE EVIDENCE OF SALT?

SIR,—With reference to Mr. J. A. Robbie's interesting account of Turonian chalk at Winterbourne Abbas containing Albian and Cenomanian pebbles,[1] an alternative source of the coarse material may be suggested.

During 1948 we observed that the almost circular anticlinal inlier of Jurassic rocks at Compton Valence, 1½ miles north-west of Winterbourne, differed markedly from other south-country anticlines in pattern and might well be due to a non-emergent salt plug. In view of the salt-bearing marl proved in the Keuper of the Puriton borehole, 33 miles further north-west, this suggestion is not unreasonable. It will be recalled that G. M. Lees and P. T. Cox have already expressed the view that the tectonics of South Dorset are most readily explicable by the presence of a plastic series at depth.

Preliminary field examination confirmed that the sharply upturned dips recorded by H.M. Geological Survey in the Upper Greensand and Chalk near the Jurassic contact could have been produced by diapiric movement. It also showed that there was little hope of adding to data on the Jurassic (known only to be in part selenitic clay, presumed Oxfordian) without deep pitting or boring.

Through the courtesy of the landowner, Mr. W. D. Chick, the D'Arcy

[1] *Geol. Mag.*, lxxxvii, 1950, 209–213.

Exploration Company was able to use a shallow drilling outfit to sink a borehole on the crest of the structure for additional information. While this was in progress a small outcrop of Fullers Earth Rock with the characteristic brachiopod fauna was located near by, and the boring passed from just below this level into normal Upper Inferior Oolite, reached at 164 feet, in which operations were suspended.

Although, of course, in no way conclusive this additional evidence tended to support our view that the Compton Valence structure is of salt dome type for the nearest main outcrop shows Cretaceous resting upon Oxfordian and Kimmeridgian rocks. It consequently provides a good alternative source for the very local Winterbourne Abbas conglomerate. As Mr. Robbie recognized, there are several difficulties about derivation of the pebbles from the Abbotsbury anticline, whereas a slight heave of deeply buried salt much nearer at Compton Valence might well produce just this effect.

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16th June, 1950.

N. L. FALCON.
P. E. KENT.

SYNONYMOUS HOMONYMY AT GENERIC LEVEL

SIR,—Apropos Mr. L. Bairstow's letter (*Geol. Mag.*, lxxxvii, 1950, p. 226), the following seems to be a genuine case, and it illustrates an unusual mode of operation of the rules governing type designation.

The ammonite genus *Blanfordia* Uhlig 1905, non Adams 1863, was renamed *Blanfordiceras* by Cossmann (1907, *Revue crit. Paléozool.*, xi, 64), but no type was designated by either Uhlig or Cossmann. In 1924 L. F. Spath (*Pal. Indica*, ix, mem. 1, p. 16) wrote "*Blanfordiceras* n.n. olim '*Blanfordia*' preoccupied". In 1923 the combination *Blanfordiceras wallichi* had appeared in another paper by Dr. Spath (*Quart. Journ. Geol. Soc.*, lxxix, 302) without explanation or indication that the generic name was new, and in 1925 (*Mon. Hunterian Mus. Glasgow*, Coll. Foss. Somaliland, p. 145) appeared "*Blanfordiceras* Spath", with a footnote stating that "the type is *Bl. wallichi* (Gray) [1830], pl. C, fig. 3". Thus, it appears that *Blanfordiceras* Spath 1923 is an independent synonymous homonym of *Blanfordiceras* Cossmann 1907, both being nomina nova for *Blanfordia* Uhlig 1905.

Further, since *Ammonites wallichi* Gray is type species by monotypy of *Blanfordiceras* Spath 1923, by Article 30, II, f, *A. wallichi* Gray is also type species of *Blanfordia* Uhlig (of which it was a syntype), and therefore also of the valid *Blanfordiceras* Cossman 1907.

SEDGWICK MUSEUM,
CAMBRIDGE.
June, 1950.

W. J. ARKELL.

REVIEWS

STRATIGRAPHY AND PALEONTOLOGY OF THE BROWNSPORT FORMATION (SILURIAN) OF WESTERN TENNESSEE. By T. W. AMSDEN. Peabody Museum of Natural History, Bulletin 5; Yale University Press (London: Geoffrey Cumberlege), 1949. pp. viii + 126, with 30 figures and 34 plates. Price 40*s*.

Some forty pages are devoted to the stratigraphy of the Brownsport Formation and to its correlation, the remainder to specific description of the fauna. A general Niagaran age can be assigned, but closer correlation leads to the view that the Brownsport strata are unrepresented in the Niagaran succession of central and western New York. The proportion of new species described is high, particularly among corals and brachiopods, and a new genus of Tabulate coral (*Romingerella*) is proposed. The illustrations are well-reproduced and the thesis constitutes a notable addition to the faunal lists of the Niagaran.

O. M. B. B.

PETROGRAPHY OF THE ISLAND OF HAWAII. By GORDON A. MACDONALD. United States Geological Survey, Professional Paper 214-D, 1949. pp. 45, 3 plates and map.

A detailed and important account of the petrography of the various lava series on the Island of Hawaii, followed by a section on magmatic differentiation.

S. R. N.

AN INDEX OF MINERAL SPECIES AND VARIETIES ARRANGED CHEMICALLY. By Max H. HEY. Printed by order of the Trustees of the British Museum, 1950. pp. xx + 609. Price 30*s*.

The first part of this very useful work consists of a chemical index of all known minerals. The index is arranged in sections based on the anion present (oxides, sulphates, silicates, etc.) and these are subdivided into subsections based on the dominant metal, or metals, in the mineral. Each section, subsection, and mineral species within a subsection is numbered, cross references are given where necessary, and every species name is followed by one or more references to literature. The second part comprises an alphabetical index of accepted mineral names and synonyms with, in the case of accepted species, a reference to its position in the chemical index. On p. 81 the heading should be 14.1.1 and not 14.1, while on p. 149 the heading should be 16.9.31 and not 16.19.31.

S. R. N.

VOLCANOLOGICAL OBSERVATIONS. By F. A. PERRET. Carnegie Institute of Washington, Publication 549, 1950. pp. xi + 162, 117 figures. Price $5.00 paper covers, $5.50 cloth binding.

In this remarkable monograph the late Dr. Perret has collected together many observations on volcanoes which he had made but which had not been published in his previous works. There are eight chapters dealing respectively with the greater solid constructions; the volcanic liquid; the gaseous element; electric and atmospheric phenomena; volcanic vegetation; volcanic ejectamenta; gravitational and volcanoseismic phenomena; experimentation—field and laboratory; diagnosis and prediction, and the whole is excellently illustrated. As Dr. L. H. Adams says in his foreword, "The series of monographs of which this is the fourth and last will stand as an enduring monument to a great volcanologist."

S. R. N.

DIE ERZMINERALIEN UND IHRE VERWACHSUNGEN. By PAUL RAMDOHR. Akademie-Verlag Berlin, 1950. pp. xvi + 827,431 figures. Price DM.88 paper covers, DM.93 bound.

This is intended to be both a textbook and a work of reference and is divided into two parts. The first (pp. 173) contains a general description of ore-forming processes and mineral paragenesis, and a detailed account of textures and structures developed in individual ore-grains and aggregates during growth, unmixing, and replacement. The second, and major portion, gives a systematic account of the ore-minerals and follows the lines of the second volume of the *Lehrbuch der Erzmikroskopie* (Schneiderhöhn and Ramdohr, 1931) but the material has been brought up to date and more data is given. The figures illustrating the text (mostly photomicrographs) are numerous and, on the whole, good. There is a bibliography with 804 entries.

As a textbook the work would have gained by the addition of chapters on reflected-light optics and on etch reactions and it is a pity that the Schoenflies notation for space groups is used throughout instead of the more useful Hermann-Mauguin notation.

The book should prove of value to all those who study ore-minerals, but the cost is high.

S. R. N.

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